METALS and ALLOYS

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This Month—Wartime Engineering Achievements

Every Month

Metallurgical Engineering Digest

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The Production Front

by Harold A. Knight
News Editor

Immediate aims after Axis defeat—reconversion and guarding of the peace. . . . Stockpiling bill "one of most important pieces of legislation." . . . Always arguments on our metal resources. . . . One authority complacent on iron, copper and zinc. . . . Popular press sometimes worried.

Despite war depletion we are "one of the wealthiest nations on earth as to minerals." . . . Rapid obsolescence of weapons dictates prompt scrapping. . . . Among new weapons are glider-borne tanks, aluminum landing mats, tank destroyer that can negotiate roughest going yet achieved.

Jeep is proving our most versatile weapon. . . . Sub-zero treatment rapidly takes place in metal processing. . . . Robot bomb is exceedingly simple mechanically. . . . Our far-flung soldiers are good salesmen for U.S.A. . . . More about p.w. automobile. . . Goose-stepping and heiling days about over.

Metal Supplies and Stockpiling

Immediately after the Axis is defeated, the United States will be engaged in two principal projects: First, reconversion back to peace, and second: Preparation for defense against another war, or keeping of the peace.

Common to both of these are our supplies of metals, a phase of this war in which we have been very fortunate, since major scarcities lay outside of metals, or in lumber, paper, rubber, etc.

Classed by Senator Carl Hayden, Arizona, as "one of the most important pieces of legislation to pass the Senate since I have sat in that body," the metals and minerals stockpiling clause of the Surplus Property Bill was passed in late August. It provides that all Government-owned accumulations of strategic metals (and minerals) be transferred to a Government-owned agency and stored for the next national emergency. Included are all metals listed in either Group A or B as determined by the Army and Navy Munitions Board on March 6, 1944, and embracing ores, concentrates, alloys, scrap and partially completed fabricated articles.

Many statements and counter-statements and opinions have been expressed in recent months over stockpiling of metals. One statement is to the effect that when the next war comes certain metals now strategic or critical would no longer be considered so, hence no need for stockpiling. Our rebuttal would be that metals are basic, and no matter how great the change in design and functions of future weapons, the same old metals will be needed.

Another theory is that by reverse lend-lease we should build up our stockpiles from foreign metals almost exclusively, allowing our own metals to stay in the ground as a reserve. Many, in fact, have the opinion that American metal resources are virtually exhausted. Typical was an editorial in the *New York World-Telegram* on "But Will the Supply Hold Out?"

Typical Belief in Mineral Scarcity

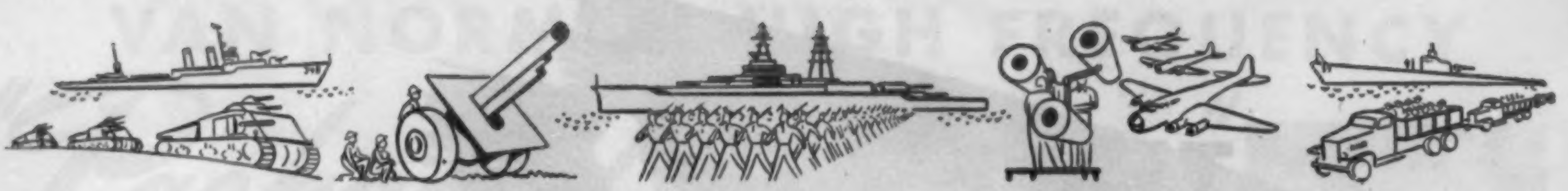
In brief the editorial stated: Our Lake Superior iron ore will last at present consumption (90,000,000 tons yearly) only six to ten years; our deposits of high-grade copper are practically exhausted; our zinc has almost reached the vanishing point; we depend on imports for nickel and tin; bauxite resources are meager. Only of coal have we plenty.

There followed a letter to the editor of the *Telegram* from Evan Just, editor, *Engineering & Mining Journal,* a gentleman certainly in a position to know what he talks about. Said Mr. Just, in essence:

"Present rates of mineral consumption are double those of prewar, and there is no expectancy such rates will continue. The over-all supply of high-grade iron ore is expected to last 20 years or more. Means are now at hand to use our enormous low grade deposits. Costs of low grade over present high grade will be so little more that final consumers—possibly even industrial consumers—will never know the difference.

We Are Used to Low Grade Copper

"As to copper, we have depended on low grade ores for a long time, anyway. Our copper reserves are far from being exhausted. As to zinc,



the most pessimistic count on local supplies to fill half our needs into the indefinite future. We have always depended on foreign nickel and tin, so things are no different. Our bauxite reserves were never much in the first place, but there is plenty in this hemisphere. We can make aluminum from clay."

Concludes Mr. Just: "The situation does call for competent scrutiny and the development of a national policy based on sound reasoning, but we still remain one of the wealthiest nations on earth in terms of minerals."

So, having dismissed with a calming hand metal supply bugaboo worries of the future, shall we scrutinize some of our most modern weapons, born somewhat late in the war?

Let's Inspect Some Modern Weapons

Germans were reportedly shocked to see tanks emerging from gliders dropped on Normandy. One of the first of these tanks silenced, within two minutes of landing, a German gun post that had been causing heavy casualties among Allied ground forces. This tank-carrying glider, the Hamilcar, has a wingspread greater than a Lancaster 4-engine bomber.

The new tank, designed for the glider, has been called "The Locust" by the British. This trump card was saved for the main invasion. The tank reaches the place of combat while in fresh mechanical condition. It is small enough to ride comfortably in the belly of the glider, but big enough to wreck the enemy.

Interesting, too, are the new aluminum landing mats, logical in view of the more ample supply of this light metal. They do not replace but supplement the steel landing mat. They will prove valuable where transportation is extremely difficult or speed is imperative. Weighing one-half the steel mat, it will pave the way for bombing Tokyo through advance air fields in China, Burma and Pacific Islands. Over 45,000,000 lb. of aluminum are called for in the original program. Many peace time applications come to mind.

At first we could not tell the difference between a tank and a tank destroyer until we noticed the latter has more gun and less tank. Our newest pride of destroyer is the "Hellcat" or M-18, with 76-mm. cannon and 55 mi. per hr. speed. It has effective artillery range of over 7 mi. It weighs 19 tons, has welded armor plate hull and 360° revolving turret. It can negotiate rougher going than any other motorized artillery yet made. A feature is a new type individual wheel suspension, incorporating torsion springs, double-acting shock absorbers and compensators, making for unusual level riding qualities. Fore and aft pitch are greatly reduced. It is virtually impossible to "throw" the track in sharp turns at high speed.

Let's Beat Obsolescence!

Again we learn how rapidly weapons become obsolete. Our Garand rifle is our only major equipment not materially altered since Pearl Harbor. Witness the parade of bazookas and other offshoots of the rocket; the flamethrower, tanks emerging from gliders, the versatile bull dozer, the many types of Radar.

Observe the many old timers put into modern dress, such as the battleship, the balloon, the rubber-tired big gun, the G. I. canteen of plastic. Our soldier has a brand new friend to whom he is as devoted as to his dog—the jeep.

Our eyes first opened on obsolescence in this generation when the Maginot Line was outflanked and breached like an egg shell. On the outgoing trip for the Germans in 1939 the Siegfried line was considered the latest for invulnerability; on their return trip that line is just another obsolescent engineering piece.

Yes, yes—but what of it? This—the time is near when we unscramble our war equipment. Let's scrap most of it with a bold, decisive hand. Let's retain our "know how," blueprints, skeleton plants and machinery, ever using imagination on new weapons.

Let's beat obsolescence to the punch. Let's retain mostly a strong potential for defending ourselves again when necessary.

Personality and Versatility

Meanwhile our jeep becomes more versatile. An arc welding unit has been mounted on the ¼ ton 4 by 4 truck for on-the-spot repairs near the front lines. It can go over rough territory and its smallness makes it a poor target. It can be landed with early waves of a landing invasion, can penetrate into deep jungles via narrow trails.

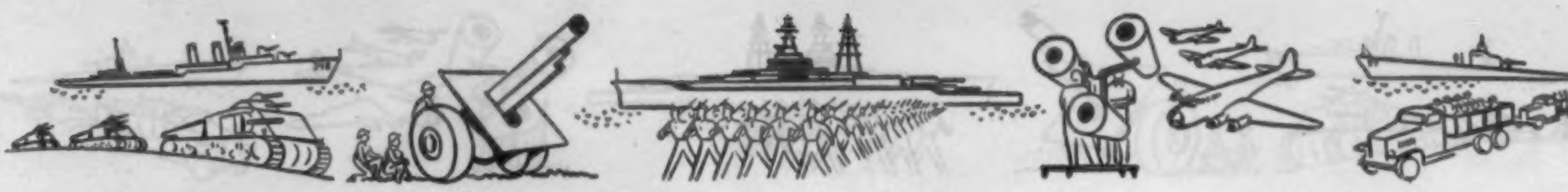
Who'll Name Sub-Zero Technique

"'Deepfreeze' is a purely arbitrarily-coined word as well as a registered trade mark. A registered trade mark such as 'Deepfreeze', or any derivations thereof, should not be used in a descriptive sense in any text. Otherwise, the trade mark or its derivatives may become common words of the English language, whereby the trade mark value would be destroyed.

"If the name, 'Deepfreeze' is used in any editorial manner, it should be used only as a noun, and not as an adjective or a verb. When used, it should appear in all caps, or capitalized and enclosed by single quotes. May we ask you to kindly observe these legal restrictions in the use of the name, 'Deepfreeze'?"

Such is a letter we received from a representative of the Deepfreeze Div., Motor Products Corp., Chicago, manufacturers of refrigeration cabinets for use in the food and metal industries.

Now, let's witness an innocent (no doubt) violation of the above ruling. A Joshua Hendy Iron Works official was discussing raw material for a new composite gear cutting hob. Among possibilities are, he said, "nitrided, chromium-plated, high-



speed steel with *Deepfreeze* [Italics, ours], Stellite, or Tantung strips."

All of which sends us off on several lines of thought. In the first place, it comes home to us that a new process in the metal treating industry is becoming established rapidly. We are beginning to encounter several references to sub-zero treatment of metals and the terms are entering technical handbooks for the first time. At the annual A.S.M. convention at Cleveland this month, papers for the first time and a panel meeting are devoted to sub-zero treatment. METALS AND ALLOYS has by now in recent months published four feature articles on the subject.

So, at the start there is need of correct terminology. "Deepfreeze" is not the correct descriptive word in the first place when applied to metals. Metal actually freezes at the point where it solidifies from the molten state. "Sub-zero treatment" is accurate but somewhat cumbersome. An* office mate of ours suggests "Deepchill."

In other lines of the metal industry erroneous or, at least, unfortunate terminology crept in. Whoever invented, for instance, "spelter?" Why not have said "zinc" in the first place? Campaigns have been conducted since to abandon "spelter" for "zinc."

So, gentle reader, what term or phrase do you propose, since we can't—and don't want to—use "Deepfreeze?"

Another twist our thoughts have taken is why Deepfreeze Div. takes steps to limit the use of their coined word. Yes, that is common procedure. You recall what universal application "Frigidaire" received in earlier days of electrical ice boxes. Yet we, neither patent attorney nor advertising man, should think a manufacturer with a coined name would welcome that word on every tongue.

We are a metal treater. See? We have decided that "deepfreezing" our tool steel will improve it. See? We get a catalog from Deepfreeze Div. See? What more natural move than that we automatically and without much thought order the Deepfreeze equipment—a word that has imprinted itself into our subconscious mind? See?

Principles of Robot Bomb

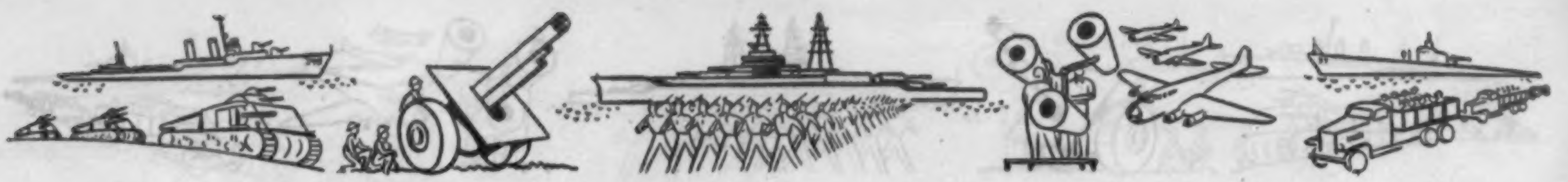
Mechanical principals of the German robot, "buzz bombs" or "doodlebugs" are simple. Chief action takes place in the tapered tube, 11 ft. long, that is carried a few feet above the plane's fuselage and is fastened to the tail, a tube with which all are familiar who have seen photos of these robots. At the forward or wider end of the tube are slots, such as in a harmonica, on the immediate inside of which are spring steel shutters.

These shutters rhythmically close and open the slots. When open, the air rushes in to combine with fine jets of gasoline to form an explosive mixture. The explosion closes the shutters, hence the exploding gases can escape in only one direction, the tapered rear of the tube, this driving the entire glider bomb forward at 300 miles per hr., tapering off to perhaps 200 miles. When pressure is relieved somewhat inside the tube by the escaped gases, the outside air forces the shutters open and the cycle is repeated.

The closed shutters somewhat resemble in principle closed valves in an automobile engine—but there is an important difference. The valves are closed mechanically to gain compression and seal the combustion chamber just prior to the explosion;

STRESS RELIEF By GILBERT

She used to be a crane operator for Zaney Steel Company



in the robot, shutters close a split second *after* and *because of* the explosion.

In the body of the plane are two large spherical bottles containing compressed air that force the gasoline spray in metered quantities through fine jets. Ignition plugs tend to the firing of the explosive mixture. Thus, in the robot's propulsion there are no compressor, turbine or rocket apparatus. Materials used are cheap—but why not?—the life of the contraption is short, for it does its dirty work only once—and that is once too often!

The passing of the cycles, as represented by the opening and closing of the shutters, causes the throb, pulsating or rhythmic noise that so many British observers have mentioned—or as one graphic description put it: "Like an old-time Paris taxicab coming down a cobbled street."

Consumption of gasoline runs up to 1 gal. per mile. Range is 150 miles. The explosive head of the V-1 bomb, housed in a thin metal casing, weighs a net ton.

G. I. Joe: Super Duper Salesman

How will we keep our tremendous production facilities occupied when peace comes? METALS AND ALLOYS roughly sketched some possibilities in an editorial several months back. One of the points was made that our soldiers and equipment, scattered to the far corners of the globe, are of themselves excellent salesmen of American goods, all of which should serve well in coming export rivalry.

Now we read in the leading article of *Foreign Commerce Weekly*, Aug. 26, 1944, much the same ideas we expressed. The title of the article is "G. I. Joe—Super-Advertiser and Salesman?" One of the subdivisions of the article is headed, "Walking Chamber of Commerce."

We can't resist quoting a paragraph, which in turn was quoted from *Stars and Stripes*, regarding the affection of the American soldier for his jeep: "The Fighting Frenchman feels the same way about the jeep, and so do the reticent British Tommy, and the pint-sized Indian Gurkha, and the New Zealand Kiwi, and the Canadians, and the Italians, and the Poles, and even the Germans, who will discard their not-so-sturdy Volkswagon for a jeep any time they can get it. Probably the Fifth Army soldier who feels most intense about the jeep is the Moroccan Goumier. You can always see him racing along as fast as the jeep will go, wearing his sack-like 'jellaba,' with his pigtail flying in the wind and an almost-laugh on his face."

In another article in the same issue we learn: "Post-war sales of machinery to the other Americas can reasonably be expected to double or triple the pre-war level that was somewhat in excess of $100,000,000 annually, according to W. H. Myer, Chief of the Machinery and Motive Products Unit, Bureau of Foreign and Domestic Commerce."

Post-War Automobile, Again

With another meeting of the Society of Automotive Engineers comes another crop of predictions concerning the post-war automobile. As time passes, predictions become bigger and better.

Distributor points may be replaced by electronic tubes, as there is need for more exact spark timing. New ignition systems are being developed that may eliminate the present high tension secondary leads with their accompanying tendency to leak and sometimes even cross fire. Spark plugs are being developed for longer life, even with heavily leaded fuels. Because of better alloy steels, it may be possible to use more economical plain valves.

More even distribution of explosive mixture among the cylinders may result by adapting injection carburetion of today's aircraft engines, of particular benefit for transportation in high altitudes.

These predictions were made by R. S. Baster, vice president in charge of engineering, White Motor Co. He said further that aircraft quality, 90 octane gasoline, will be available for engines made from aluminum, magnesium and other light alloys, costing no more than cast iron.

"It is only through increased thermal and mechanical efficiency that we may expect to extract more actual foot pounds of work from a dollar's worth of fuel," he said.

Argentina a Menace? Please Read—

Must we stay armed after this war because of such threats as fascist Argentina? No, not because of Argentina. Germany and Japan will be whipped so badly, decisively and humiliatingly that goose-stepping, swastikas, heiling and doctrine of being descendants of the Gods will be laughed off the face of the earth for the 1000 years that Hitler figured the German people would rule supreme.

"Nothing succeeds like success" and, in reverse, one might say: "Nothing so fails as failure." In these columns we have made too many personal references. Pardon just one more. When a small boy, we spent two and a half years in Alsace-Lorraine when the famous Kaiser ruled with iron one hand. The apple of our eye was a toy soldier's helmet and a shiny tin sword. We strutted and marched with the best of them. We had fallen in with the mass psychology all about us.

So during the past few years too many nations have fallen for the tinsel of military might, totalitarianism et al. But that tinsel is fast becoming tarnished from the corrosive influences of Allied military might, backed up by love of justice. No, a year or two from now Argentina, if still rattling the sword, will do so sheepishly if in public, and preferably out behind the barn where nobody can see. Spain and any other countries that may have nourished secret fascist ambitions will wither and die, as to their fascist leanings and sympathies.

Why, in another year or two the 10-year old boys will find it hard to play soldier—none of them will be willing to make believe they are Nazis or men of the once Rising Sun. No one to play enemy? Aw, Gee!

The War and Engineering Research

When the history of the metallurgical engineering developments of this war is written, it will be replete with intensely interesting and astonishing facts. As a result of the war effort, there has been more investigative research, intensively prosecuted, than in any similar corresponding period in our experience. The practical and technical results have been numerous.

On other pages we publish a survey which, to a limited extent, emphasizes this fact. Our analysis of the replies shows that certain of the authorities emphasize a few vitally important achievements as outstanding—light metal technology; the NE steels; the new heat-resisting steels; progress in foundry engineering, particularly centrifugal and precision casting; boron in iron and steel, heat-treating technique; and so on, all highly essential in the victorious prosecution of the war.

There are, however, many other important achievements of an engineering and metallurgical nature that have not thus far been made public, some of which may be even more vital to the war than those more or less publicized—they are still military secrets. But eventually they will probably be made known and will make the history of these developments all the richer.

The extent of the cooperative effort expended in all these studies is very little appreciated by many. These researches and investigations have been largely carried out by the War Metallurgy Committee, made up of leading authorities, by research laboratories, by the metallurgical engineering staffs of leading steel, metal, and allied companies, and by others.

Into the success of this effort has gone the pooling of the knowledge of all of those participating—an example of patriotism of the most unselfish nature. It has all been a most potent factor towards Victory, and also a glorious tribute to the welfare of the nation. And those partaking in this work deserve the gratitude of all the people.

It's "an ill winde that bloweth no man to good"—said John Heywood years ago. Technological research as a result of the war has reached a level unexcelled in the past. —E. F. C.

Getting the Most from the Metal Show

The National Metal Congress and War Production Displays return this year to something approximating their former magnitude. The exposition will be the largest Metal Show ever held, and the Congress will provide a greater profusion of technical papers and meetings (despite the transfer of the Wire Association's convention to Pittsburgh that week) than in any previous year.

Because of its size and the complex and often simultaneous demands the Show makes on an individual's time, a few suggestions based on several annual experiences as an initially eager but ultimately

Projections of the spectrum of a steel sample being studied by the spectroscopist.

The Case Against "Tramp" Elements

Ten minutes after a sample of steel is delivered to the Inland laboratory its chemical content is clearly and permanently recorded on spectrographic film. This film is greatly enlarged by projection, and is studied by the spectroscopist. There is not a chance for any "tramp" element to pass undetected.

The apparatus by which these checks are made is known as a spectrograph. A small specially prepared sample of steel is placed in the apparatus, where it is quickly vaporized by an electric arc, and the spectrum recorded on photographic film.

Inland uses the spectrographic laboratory for frequent and rapid tests while heats are being made. But this is only one of the many methods used by Inland to control the quality of steel—steel that is uniform from order to order—steel that is easily fabricated with minimum wastage.

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weary visitor to the Show may be helpful. As early as possible—before leaving home if you can, immediately on arriving at the Show otherwise—study the technical programs of the participating societies, check off those meetings you must attend, and set up an hour-by-hour schedule of your time while at the Congress, resolving conflicting demands as painlessly as possible and leaving some open time for perhaps the most important and profitable activity—chatting in the halls and lobbies.

Be sure to leave generous periods for inspecting the exhibits. The number of exhibitors is larger than ever this year, so it might even be wise to allow *extra* time. And when planning to visit the Show, remember that a large number of exhibitors will maintain operating installations in their booths, where they will be glad to heat treat, surface-harden, weld, braze, cut, grind, polish, clean or otherwise process parts whose fabrication or treatment may be vexing you; bring along a few pieces and see if you may not have your problem solved "right before your eyes" at the Show.

Among the things which in our mellow, gray-bearded wisdom we should (probably futilely) advise *against* are: (a) coming to Cleveland with neither a hotel reservation nor the possibility of finding a thin friend who does have one, (b) neglecting to arrange for your return railroad or plane reservation until the day before you need it, and (c) adhering expiringly to a schedule in which only the long alcoholic night follows the long technological day—remember that you, too, have a yield point!

And when you're at the Show, stop in at Booth D-431 and say "Hello" to the M & A editors. We'll all be out there as usual, eager to exchange information or, perhaps, to receive a few bouquets or brickbats that you've been saving for personal delivery!

—F. P. P.

Alloy and Electric Steel

Statistics are usually shunned by the average reader, but they certainly often have a value not always appreciated. A critical analysis very seldom fails to bring out a definite trend or to establish an economic fact. If one delves into the data covering alloy steels, for example, including the process by which they are made, some interesting facts are deduced.

The trend in total alloy steel output this year to Aug. 1 (the latest data of the American Iron and Steel Institute) is downward. The rate of output at 902,430 net tons per month to Aug. 1 this year is about 17.75 per cent less than the peak output of 1943. It is also approximately 6 per cent less than the 1942 volume. But the record this year is over 3¼ times the 1939 output—a startling expansion in less than 4 years.

The stainless steels are a substantial proportion of the alloy steel production—in 1943 their total was about 3.5 per cent of the alloy. In 1942 it was 3 per cent, and in 1939 it was 5.5 per cent. This progressive decline in these proportions is evidence of the relatively large expansion in the total of alloy steels. Data for 1944 are not available, but there is not much reason to think that the situation is different from 1943.

In electric steel some interesting facts are evolved. The most significant one is that, despite the decline in total alloy steel production this year to Aug. 1, the proportion of electric steel has increased. In 1943, the percentage of electric steel of the total alloy steel output was about 30 per cent. For the first 7 months of this year this ratio has expanded to 34.5 per cent, or the highest on record. In 1931, only 15.8 per cent and in 1939 about 23.3 per cent of the total alloy steel was made in electric furnaces.

Another sidelight on the whole picture is a bird's-eye-view of the expansion in alloy and electric steel in 30 years. In 1913, the alloy steel output was only 714,357 gross tons—in 1943 it was 13,149,818, which is an expansion of nearly 18½-fold in 30 years.

More astounding, however, is the increase in the volume of electric alloy steel—in 1913 only 11,264 gross tons was made in electric furnaces. This had expanded to 3,932,743 tons in 1943, or nearly 358 times greater in 30 years—a phenomenal achievement.

Some of the facts cited tend to show that electric steel is more than holding its own. They may also have some bearing on the future of electric steel—a question uppermost in the minds of many in the whole field of steelmaking—the competition between electric and open-hearth steel, particularly in the alloy field. Prophecies as to this are dangerous at present.

While the future is bright for alloy steels, whether made in the electric or open-hearth furnaces, it is probable that the war records will not again be equalled in many years.

—E. F. C.

ENGINEERING ACHIEVEMENTS

WAR—OUR CURSE, OUR TEACHER

War, the most horrible of all the crimes that man visits upon himself, does have one or two consolatory aspects: At the same time that it reflects the worst in men, it also reveals and develops the best in them —their courage, their personal nobility and capacity for sacrifice, their eventual perception of a normally elusive ideal, their patriotic co-operation, their ability to achieve great things technically in a fraction of the time that would normally be required.

While we hail all these wartime achievements, it is the war-impelled and victory-speeding *technical* achievements to which we pay special tribute in this third wartime "engineering achievements" issue of M&A. The list of outstanding achievements in the fields of new materials and metal-working methods is long, as one realizes after reading the introductory survey by Mr. Cone in this issue. Some of the most important developments—the wartime materials-supply and conservation program, the genesis of the NE steels, ordnance redesigning, steel cartridge cases, precision castings, electrolytic tinning, high-temperature forced-convection furnaces, the pressure quench for armor plate—have already been saluted in previous "achievements" issues. Several others are described in this issue, some for the first time in such detail anywhere. Still others must await the indulgence of the Censor for publication in later issues.

Among the war-winning engineering achievements described in *this* issue are the new super-strength aluminum alloys of the two leading aluminum producers; the recently developed group of adhesives for joining metals to each other and to nonmetals; the production of magnesium from seawater; the new high speed milling technique using carbide tools and negative rake angles; the various methods now used to protect, pack and "package" corrodible steel parts for overseas shipment and storage; the "skin recovery" process for re-carburizing de-carbed steel; and "Martempering" and related hot-quench heat treating processes.

These are but a few of the materials war has forced us to develop rapidly or the methods we have had to evolve or perfect to crush our enemies. They are also outstanding among the new engineering materials and methods that will be the foundation for our peace-time production and design accomplishments.

To all these wartime engineering achievements, and to many others that military considerations keep shrouded in secrecy, we pay grateful homage in this issue!

—The Editors

The War's Foremost Achievements in Materials and Methods —A SURVEY

by EDWIN F. CONE

AN ATTEMPT IS MADE in this survey to obtain a coordinated appraisal of the foremost engineering and metallurgical achievements in the development of new materials and methods resulting from the war effort—really a bird's-eye-view of the picture. It is realized that there are many developments which are still secret, some of which may be more important than those already generally known and to some extent publicized. This summary of the opinions of many well-informed men refers therefore only to those generally known developments.

A series of three questions, reproduced elsewhere herewith, was sent to nearly 150 leading materials engineers, metallurgists and production men. The response has been cordial and cooperative as well as highly interesting. As might be expected, the selections of the prominent developments has been of a widely scattered nature—no large group, with one or two exceptions, agreed on one or two developments as outstanding. While most of those approached have a broad comprehension of what has happened and is still happening, their selections in many cases have been manifestly determined by the special fields in which they have been working.

By and large, however, it is a signal fact that the work that has been done, as revealed by these opinions, is both highly impressive and drastically important. The War Metallurgy Committee and others who have done and are still doing work on the problems put up to them deserve the deep appreciation of the whole nation. Unfortunately this deserved praise is not as spontaneous and widespread as it should be because only a relatively small portion of the public is capable of merited appraisal.

A running account of the results of the survey is attempted in the following paragraphs. It is perhaps unfortunate that all the comments cannot be fully reproduced since some of them are decidedly interesting. They must all be referred to anonymously according to the understanding stipulating in the survey.

THE THREE QUESTIONS

1. What in your opinion have been the leading technical achievements in the development of new materials, in the manufacture and processing of metals and alloys and in their applications, thus far in the war?
2. Which one of these would you characterize as the most important?
3. Is this one likely to develop further, and if so, what will probably be its effect on the metal working and metal producing industries in the post-war era?

The Light Metals

Much emphasis by several authorities has been placed on the aluminum and magnesium alloys—nearly 25% of the replies dwelt on these as among the leading developments, as the most important, and as likely to develop further.

Selecting as of signal importance among several developments, the aluminum alloy or 75S, an authority in the aircraft industry says that the development of high strength aluminum alloys is the most important insofar as the future aircraft production is concerned. "The possibility of developing this type of alloy to a point where it will effect worthwhile savings in weight in airframes is quite possible. The use of a high strength alloy would mean improvements in machines for metal forming and cutting, particularly the former since about 80% of the raw material used in airframe construction is in the form of sheet."

A prominent materials engineer considers magnesium technology as the leading technological achievement in the development of new materials and the manufacture and processing of metals and alloys thus far in the war. "Very little magnesium or its alloys was made or fabricated previous to the war. Now it

is a very large industry. Magnesium technology will probably further develop. It will be a competitor to aluminum, steel and copper-base alloys in the construction of airplanes, vehicles and applications where weight is a factor."

Two of the war's technical developments reported as having impressed one well-known metallurgist as being "head-and-shoulders above the average in their inception and in their possibilities for the future" are—the recovery of magnesium from seawater and the process for the continuous pouring of an ingot of aluminum up to any desired size. This latter accomplishment he believes makes practicable the continuous rolling of aluminum on a large scale.

"The expansion of the light metal industries, aluminum and magnesium has been tremendous," in the opinion of one experienced metallurgical engineer. Both of these materials have undergone many technological advances in production, alloying and processing, he says. The growing extensive use of radiography as an inspection tool has aided the production of new high strength materials with a minimum loss due to melting defects, etc. These metals will undoubtedly enter the field of engineering alloys to a greater extent in the future.

The N. E. Steels

On one development in particular there has been substantial unanimity of opinion as to its importance —the National Emergency (NE) Steels. About 25% of the answers dwelt on this.

Among the comments: One well-informed materials engineer is of the very definite opinion that the development of these steels is one of the outstanding contributions. "There is no doubt," he says, "that for many years alloys have been used in excess of requirements and the use of these special steels is going to make us more conscious of the highest physical properties obtainable and also to apply the proper steel to do the job rather than supply a steel much too good for the application."

In the last 5 or 10 yr. we have been given methods of measuring quantitatively the effect of various alloys on the properties of steels and irons, says a prominent metallurgical engineer in the foundry industry. "We have been shown that in using small amounts of alloys, the effect of one is enhanced by the presence of one or more others. These additions to our fundamental knowledge have led to great changes in our ideas on the best methods of making quality steels and enabled us to make up for shortages of steel-making alloys by the adoption of the NE steels.

This authority expresses a doubt if the latter continue in use after the war without some changes, yet he does not believe "we shall go back to the former practice of adding alloys by the bucket-full in order to make fool-proof steels." He rather believes that steels will be used with much smaller percentages of alloys, probably each containing several alloys as the NE steels do and thus secure the best properties in these steels by proper heat treatment.

These steels have been selected by a well-known chief metallurgist as one of the chief war technical

THE TEN LEADING WARTIME ENGINEERING MATERIALS AND METHODS DEVELOPMENTS

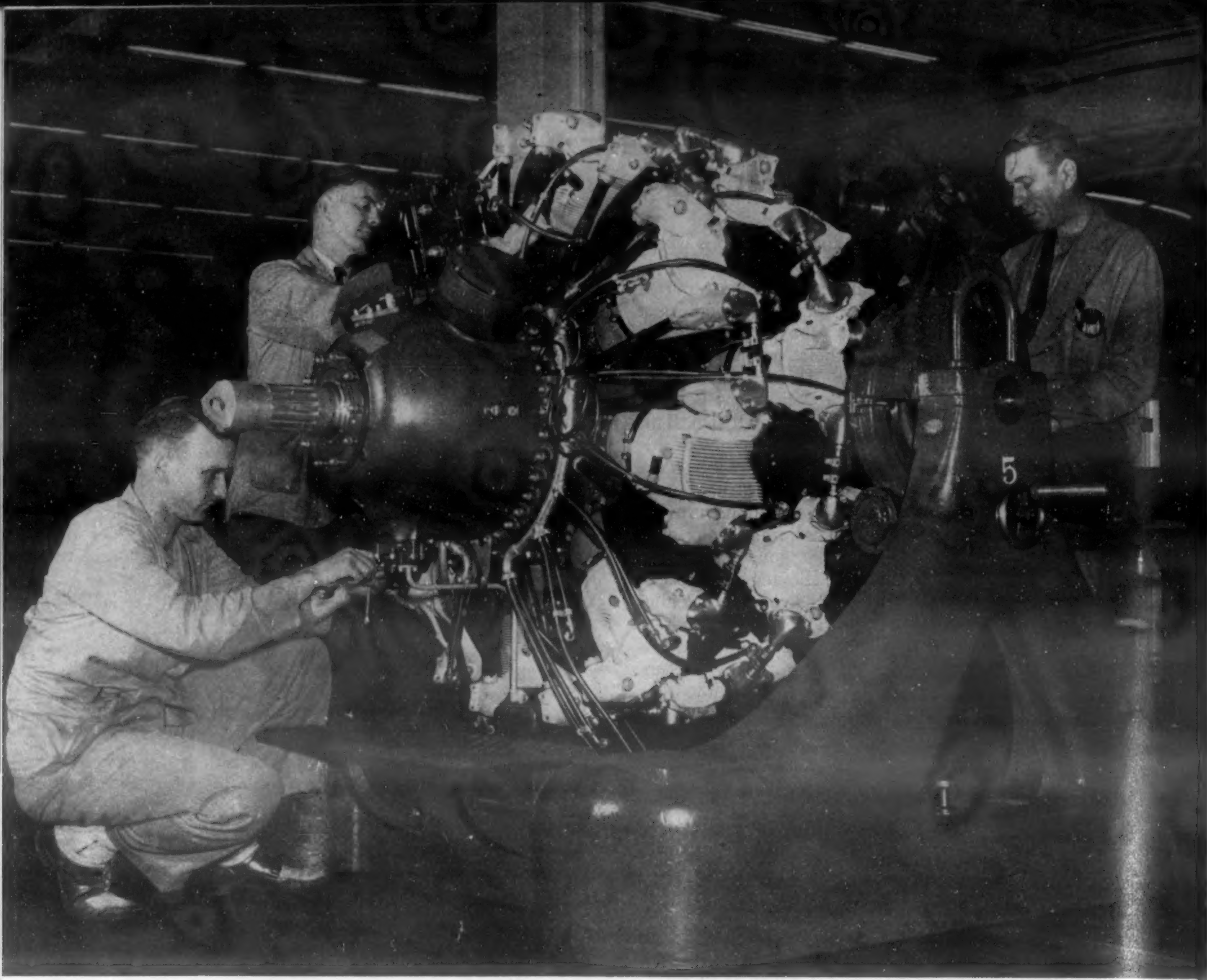
Based primarily on this survey by Mr. Cone of the opinions of leading engineers and metallurgists in the metal-working industries, METALS AND ALLOYS is proud to publish as part of this "Wartime Engineering Achievements" issue a list of the ten outstanding non-secret wartime developments involving new materials or processing methods that have made major contributions to Victory and which have considerable significance from the standpoint of post-war design and production.

These 10 leading developments all fall within the framework of 3 broad, overall achievements for which American metal-working plants, engineers and scientists as a general group, the War Production Board and Army Ordnance share top honors—(a) Expansion in metal-production, especially of steel (about 10 million-ton increase) and of light metals; (b) the conservation program—including substitution, process-conversion and salvage—that stretched our available metal supplies phenomenally; and (c) the cooperative pooling of know-how on materials and methods by all industry.

Specifically, the 10 chief wartime materials and methods developments now disclosable (listed here not necessarily in the order of their importance) are, in the opinion of the experts consulted:

1. The development and use of the National Emergency (NE) alloy steels.
2. The development of special heat-resistant steels and alloys and of precision manufacturing methods for turbo-supercharger and gas turbine components.
3. The development of new high strength aluminum alloys and of clad aluminum alloy combinations far superior to the best available before the war.
4. The production of magnesium from seawater at plants on the Texas Gulf Coast.
5. The expansion in the use of welding for fabrication, especially of ships.
6. The application of tungsten carbide tools (especially for high speed milling) to increase the output of machining operations.
7. The development and performance of heat treated cast steel armor plate.
8. The rapid development and wide use of new methods of "packaging" steel products to protect them against corrosion, particularly during overseas shipment.
9. New resin-bonding adhesives for joining metals to metals and to nonmetals, sometimes with the strength of welds.
10. The production of forged aluminum cylinder heads for airplane engines, permitting considerable increases in power per unit of engine weight.

Several other achievements of outstanding importance were also nominated and are discussed in this article. —*The Editors*



Aircraft engines like this Wright Cyclone exemplify and embody many outstanding materials-and-methods achievements—scientifically heat treated NE steel parts, centrifugally-cast cylinder barrels, aluminum and magnesium alloy forgings and castings, fine machine work, the use of brazing and other fast joining methods, new types of bearings, powder metallurgy parts, protective coatings and wrappings, etc. (Courtesy: Ford Motor Co.)

products. In his opinion certain of the NE steels will continue to be used in increasing quantity in industry although it is doubtless true that some of the alloy steels will regain their popularity and wide usage.

The NE steels with their lean alloy content proved to be as good as their richer brothers in many, many applications, insists a widely known technician who selects these as the signal development. Their success was due in large measure to better control of fabricating and heat treatment operations. He believes it is fair to say that as a result of their promulgation, new and better heat-treating furnaces were designed, better quenching oils and salt baths were developed, much greater attention was given to processing—all of which combined to increase our technical and scientific knowledge.

Other testimonies which include the citing of these steels as one of the signal developments of the war, came from the materials engineer of a large airplane organization, from an authority in the welding field, from a distinguished metallurgist in several fields, and from a foundry engineer. "What amounts to a revolution in the manufacture of steels for severe service" has taken place, is the firm belief of a prominent technologist.

High Temperature Resisting Steels

One of the most important new-materials developments during the war effort is almost universally recognized as the high temperature resisting steels—those used in superchargers, gas turbines and so on. Very little technical detail has been allowed publication thus far, but knowledge of their existence is quite general. Our knowledge of such steels and their development to perfection and practical use is one of those things that the exigencies of war has necessarily advanced to a point that otherwise would have taken years.

One of the leading executives of a large company in the alloying field declares that certainly one of the leading technical achievements which has been going

on during the war is that of the development of new and very much improved creep-resisting alloys for high temperature service. "There are a number of these compositions that have been developed"—"not much can be said about them at the moment." This man, an experienced metallurgist, feels that they "will have a post-war importance equal to or perhaps even greater than their importance at the present moment."

A most important war-time contribution in our field has been the development of heat-resisting alloys and methods of producing finished parts for high temperature superchargers and gas turbines, including jet propulsion devices of all kinds, says a prominent professor of engineering. It may be expected, he feels, that gas turbines, when fully developed, will displace both large diesel units and small steam turbines especially in transportation equipment. Many types of jet propulsion require metals which retain their strength at high temperatures. The high temperature resisting metals will enable many types of prime movers to operate more efficiently and at less cost to manufacture.

Boron in Steel and Iron

Advancement in our knowledge of the use and effect of boron in steel and iron has been markedly furthered by the war. This is quite generally admitted. One metallurgical engineer, close to these developments, feels very definitely that the utilization of minute quantities of boron as an alloying element for iron and steel is a major contribution to the war effort. This authority is "satisfied from what I know that boron will be used almost as extensively as any of the well-known alloys; the fact that so much can be done at such a low cost is going to be an item which cannot be lightly cast aside." Only the surface has been scratched, he says, as to the possibilities of the application of the element boron. A number of tests have already been completed by leading steel companies that bear out the contention that the use of boron will certainly be a post-war application and one which is going to demand considerable attention.

In the Foundry Industry

Emphasis on achievements in the foundry industry came from several sources. One authority stated that in this industry there has been considerable growth of technology, due largely to the opportunity to build complete new foundries. This proper planning, due to a proper recognition of the factors involved, has produced considerable mechanization, automatic control, and greater production of higher quality in relationship to the manpower utilized.

Another authority, a research engineer, emphasized the general progressive developments in the foundry, including particularly cast armor plate. One of the leading technical developments has been in the steel casting field—great improvement has been made in every part of steel foundry practice; the cooperation of steel foundrymen will continue. Heat treating of steel castings will continue its progress and will be applied to more and more types.

Undoubtedly one foundry development of great importance and far-reaching consequences is the liquid quenching and tempering of steel castings. This fact has been recognized by several as an outstanding war achievement. "The use of water quenching and tempering of cast steels, under adequately controlled conditions, will be greatly extended," says a leading exponent of the foundry industry. And heat-treating equipment in the better foundries will literally bear only a faint resemblance to that of a decade ago.

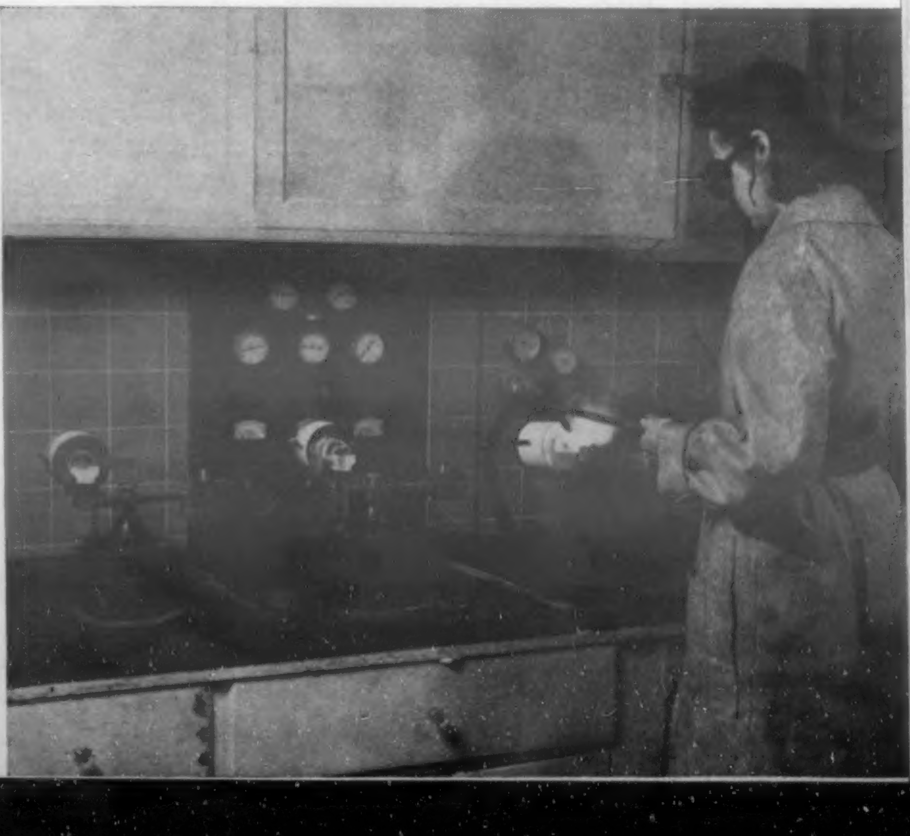
The quenching of steel castings is the most important change in processing that has been brought about by the war, is the testimony of a leading foundry engineer. All of this work has been in connection with armor production and no details may be published at this time. This treatment of steel castings will be used to a much greater extent in the post-war period, providing that current specifications can be changed. The foundry industry will be required to conduct an extensive educational campaign before this heat-treating method can be used to any extent, according to him. Practically all commercial and Government specifications now prohibit liquid quenching of steel castings except for a few specific items.

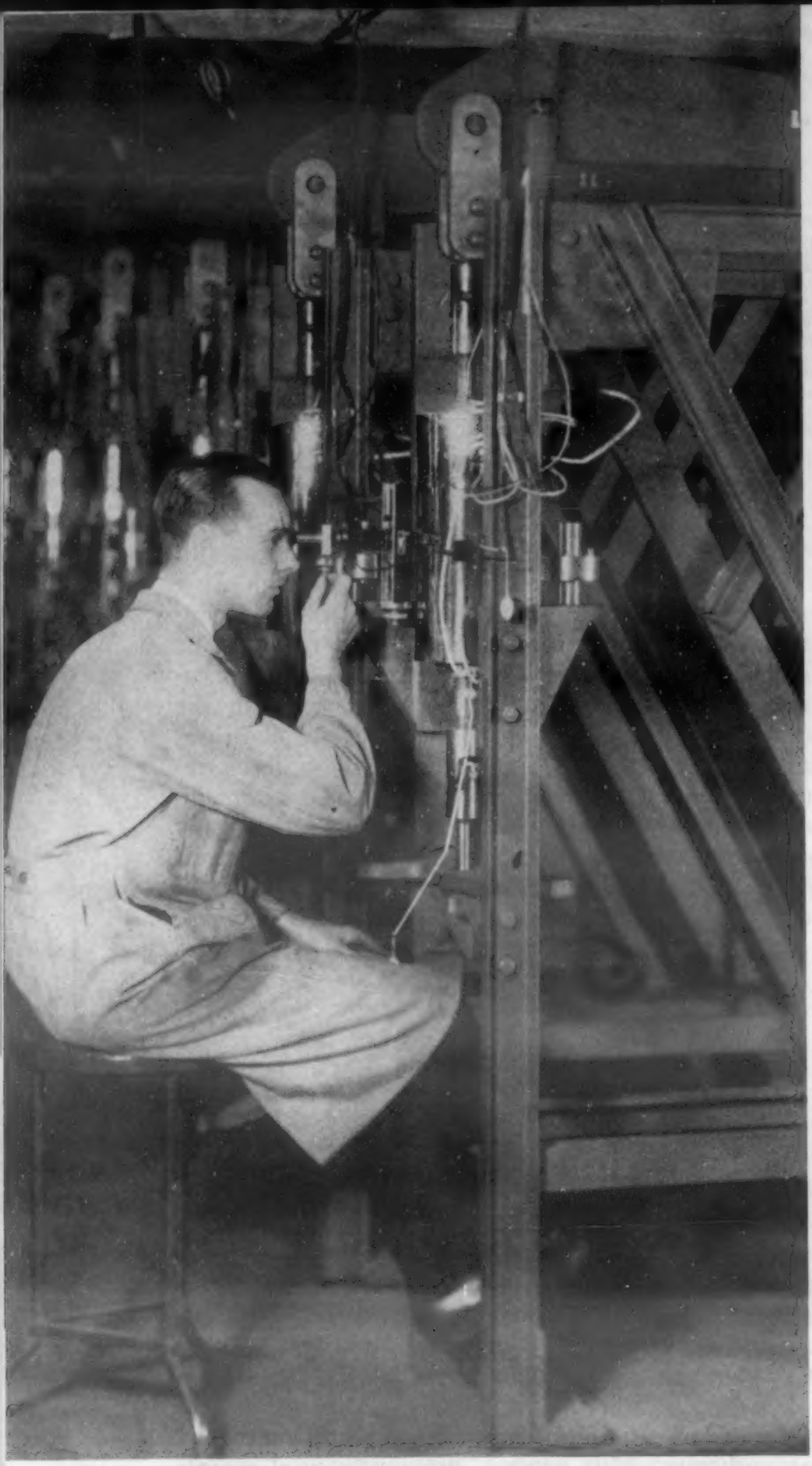
Closely allied to the general foundry industry is the centrifugal casting of metals, either by conventional methods or as precision castings. This art was called attention to by several authorities as outstanding in its recent progress.

Centrifugal casting methods have been used much more extensively, according to one authority. Better physical properties have been obtained, with excellent reproduction and minimum metal losses because of the increase in centrifugal casting. Both the ferrous and non-ferrous industries will employ this process more extensively in the post-war period. Centrifugally cast cylinder barrels for aviation engines was selected as a prominent achievement by an aviation authority.

The application of the precision casting process was noted as an important war accomplishment by one authority. This process, previously used mainly in dental work, has been and is being applied for

The precision (investment) casting method for making intricate small parts to close tolerances has skyrocketed in importance during the war. Centrifugal methods are often used in pouring the castings, as in this installation at Whip-Mix Corp., Louisville, Ky.





Creep tests like those being conducted in this section of United States Steel Corp.'s research laboratories at Kearny, N. J., are part of the development program that has given us new heat-resistant alloys for gas turbine and supercharger components.

the precision casting of highly alloyed metals, particularly metals which were not forgeable or machinable. This made possible the production of intricate parts in alloys which previously could not be used. A notable example is the supercharger used in aircraft.

Further testimony of this authority is a belief that this technique will be considerably developed after the war and will make possible the accomplishment of engineering and processes which have hitherto been impossible, due to the lack of metals of sufficient refractoriness as regards heat, corrosion and other effects. By this method there can apparently be made alloys in non-forgeable, non-machinable grades which have rather unique properties and which can be made in the finished form. A leading materials engineer gave similar opinions.

Powder Metallurgy and Carbide Tools

Powder metallurgy has been greatly stimulated by the war, in the opinion of a prominent materials engineer. Another authority testifies that this has expanded into a new and active industry. Selection of proper dies has produced parts with excellent properties and dimensional tolerances which heretofore had involved most elaborate machining. Pure powdered metals possess excellent electrical properties which cannot be obtained by conventional casting processes. Porous bearings have been utilized with perfect safety in several instances where conventional bearings will not function.

Progress in the sintered carbide tool industry is by no means overlooked. One reply, that of a very prominent mechanical engineer, is to the effect that the development of sintered carbide tools which, while not new, have extended enormously the machining and forming capacity of the country during the war has been advanced by the war. Carbide dies enable many operations such as drawing steel cartridge cases which would have been impossible without the new heat and abrasion-resisting material. The improvement made in carbide tipped tools has in many cases been in the order of 25 to 1 in production capacity. Tungsten carbide as a cutting tool and a drawing and extrusion die will enable many metals to be produced in a cheaper form for mass production after the war.

Miscellaneous Developments

In a survey of this somewhat unusual nature, several commentators included some minor developments among major ones which are both interesting and important. Among these should be mentioned the following:

Plastics: The "plastic bonding of metal to metal, metal to wood and other non-metallic material" and "plastics with glass fiber fillers."

Spectrography: "In the field of analytical control, the spectrograph has enabled extremely rapid analyses to be made in both the ferrous and non-ferrous industries. Production can be greatly accelerated and greater quality is assured. The future use of the spectrograph should not be confined only to the larger industries."

Strength of Materials: From a professor distinguished in this field—"the most interesting development during the war period is the study of the property known as technical cohesion strength. This involves a study of the conditions under which normally ductile materials break like brittle materials, even under a few loads. This subject is in the early stages of its development, but to me it seems the most important development in the field of strength of materials in the last few years."

Induction Heating: There was less emphasis on the progress in induction heating than could normally be expected. This has expanded vastly as a result of the war.

"Induction heating and brazing has advanced considerably in the past few years," is the opinion of one authority. "The use of high frequency equipment has made better industrial working conditions as well as making possible greatly accelerated production quantity with more uniform quality."

Other Items: The phenomenal increase in the country's capacity to make steel, pig iron, aluminum and magnesium are cited as achievements of decided importance.

A prominent research engineer calls attention to the "methods of heavy ordnance manufacture, including the use of welding" and "the development of low alloy steel armor plate" as signal war developments.

Selecting as one of the important war developments, the chief metallurgist of a large steel company points to the substitution of electrolytic tin plate for the hot dipped. There is no question in his mind but that it has attained and will continue to retain a prominent place in the field of tin plate production. "Eventually a large part of the production of hot dipped tin plate will be replaced by electrolytic tin plate with a saving in tin in the production of equal or better quality plate at an equal or lesser cost.

Among several accomplishments of recent vintage, one authority cites the fact that in the last two years the art of electroplating and electrochemistry have been "spot-lighted." Thick plates have not only been developed and made possible but at the present time are practical. Another of our commentators mentions as an achievement among several the development of "silver plated bearings, including the use of indium."

Technology of Steel Making

One of the impressive and vital facts, dwelt on by several authorities, is the increase in our knowledge of the technology of steel making—the proper uses of alloys and steel making technique.

A distinguished research director of a large steel company considers the outstanding achievement "a better and more widely diffused understanding of metals, particularly steels, and of what can be done with them to get new combinations and properties. I feel confident of further progress in this direction—namely, in getting the metal which, all things considered, is best for each specific purpose."

Meticulous attention to detail has been forced upon steel makers is cited by one of prominence in steel circles as a major contribution of the war. This "shows up in many ways and in some things it becomes a closed cycle, or at least a complete revolution of a spiral." The NE steels are pointed to as an example. We come to realize, however, that "all this was not done by any one individual or any one group; that cooperation was vital to the success of all their efforts, and of course cooperation was extended and received whenever necessary."

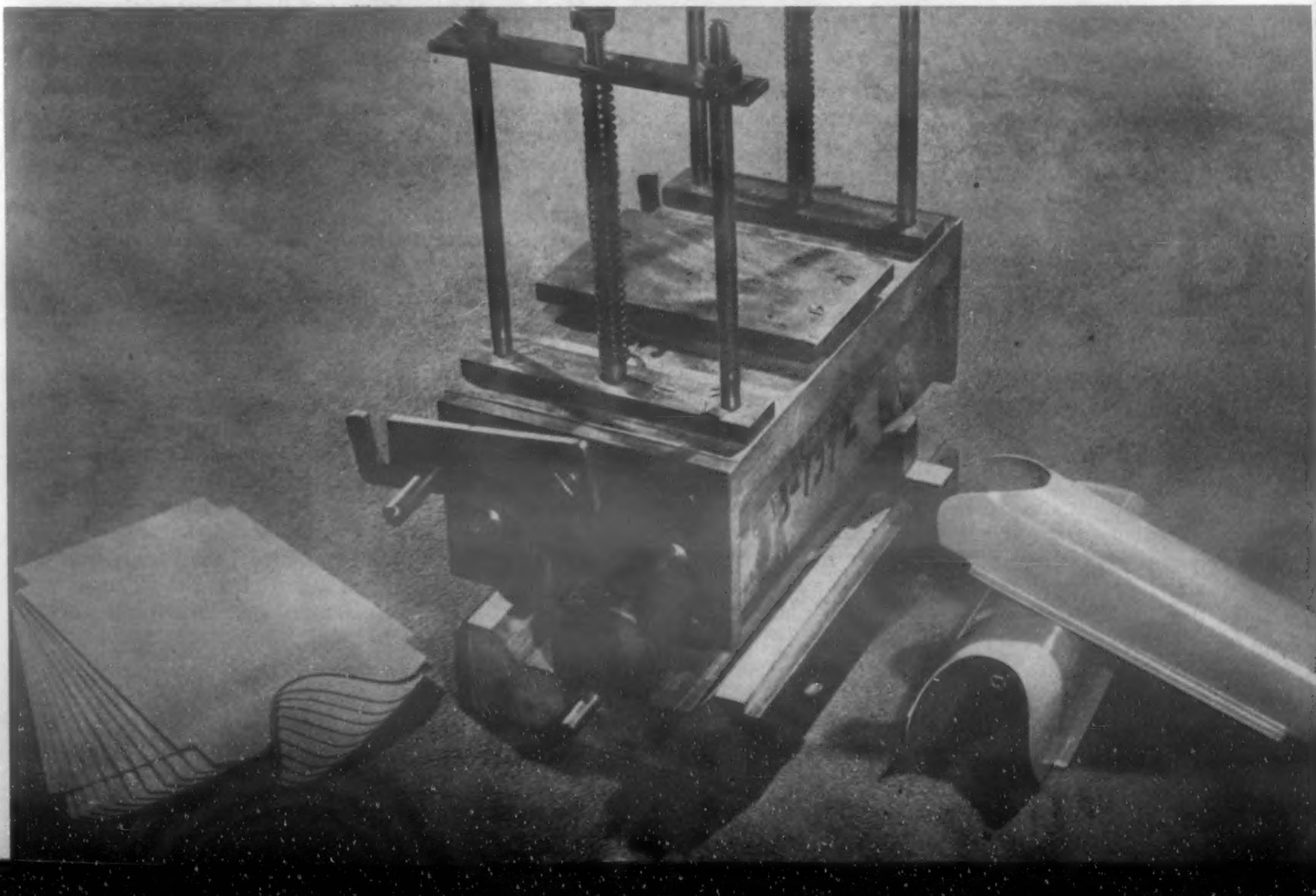
In Conclusion

One cannot conclude this survey without emphasizing the deep impression which it conveys—an impression of the great strides which have been made in most of these so-called war achievements, strides which have been accomplished in a few brief years or months, but which would have taken many years to bring to their present state in normal times. To be sure some of them are an expansion of developments originating in the pre-war period, but their expansion is important.

Also impressive is the cooperation among all types of engineers, steel producers, research organizations and others—a united effort which has solved many difficult problems, which would otherwise have taken years and duplication of effort.

Engineers, executives and many others can take just pride in all that has been accomplished. It should all tend to greater progress in the future.

Nonmetallics such as the laminated plastic-plywood sheet shown here are emerging as first-class engineering materials in many cases. The finished parts at the right can be "post-formed" on the fixture illustrated, out of blanks like those at the left, much as sheet metals are worked. (Courtesy: Formica Insulation Corp.)



75S—Alcoa's New High-Strength Aluminum Alloy

by J. A. NOCK, JR. *Aluminum Research Laboratories; New Kensington, Pa.*

ENGINEERING ACHIEVEMENTS

Foremost on the list of wartime engineering achievements in the view of many has been the development of new super-strength light metals, which have been applied to airplane construction with vastly improved effectiveness. Among these were Alcoa's XA75S and XB75S "experimental" high strength alloys, details of which were kept under wraps, until in very recent weeks one of them was officially graduated from the "X" stage and now emerges as 75S alloy—the strongest light metal in commercial existence. In this article METALS AND ALLOYS is privileged to present for the first time the complete engineering story of the nature, properties, workability and applications of this new material, certainly destined for a high place in post-war materials engineering. —*The Editors*

THE ALUMINUM CO. OF AMERICA announced several months ago that their new alloy, 75S, was in commercial production. Alcoa alloy 75S possesses a tensile strength superior to that of any other aluminum alloy now available to the aviation industry, and is intended primarily for use in the building of aircraft having superior performance characteristics. This alloy is the culmination of a number of years' intensive experimental work. Already a substantial quantity of this alloy has been made available to aircraft manufacturers, and recently a number of leading aircraft builders have designed planes in which this new alloy has been utilized as a major material of construction.

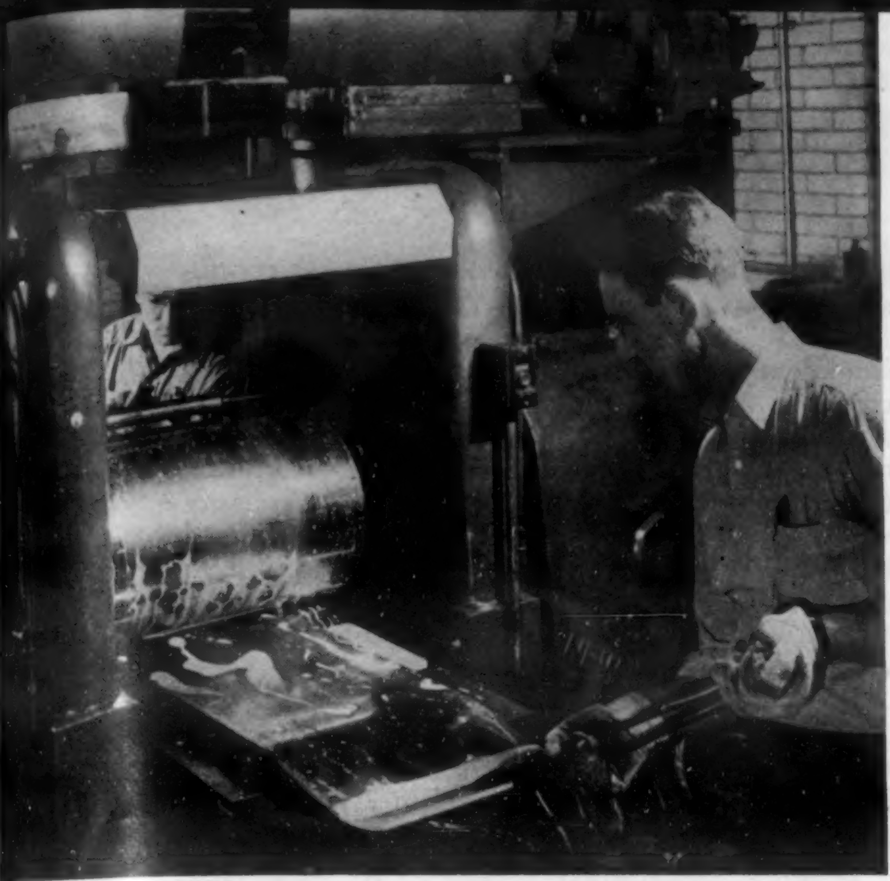
The alloy 75S contains approximately 90% Al, with magnesium, zinc and copper as its major alloying constituents. The alloy is commercially available in the form of alclad sheet and extruded shapes. The tensile strength of 75S-T (T indicates the fully heat-treated temper) extruded shapes, such as are used in aircraft wing beams, is about 88,000 p.s.i. In alclad sheet form, 75S-T has a tensile strength of approximately 77,000 p.s.i. The tensile yield strength of extruded shapes is approximately 80,000 p.s.i., and that of Alclad 75S-T sheet, 67,000 p.s.i. This latter value is 50% higher than the yield strength of 24S-T, the alloy used commercially today for aircraft construction. The compressive yield strength of 75S-T is approximately equal to the tensile yield strength.

Mechanical Properties and Heat Treatments

The Table lists the mechanical properties of alloy 75S for both alclad sheet and extrusions including the figures for Young's modulus of elasticity, the shear strength, hardness, and endurance limit.

The annealing of 75S products is accomplished by a two-stage treatment which produces maximum workability and freedom from age hardening. The first, a recovery or recrystallization stage, consists of heating for 2 hr. at 775 to 850 F.; then the material is cooled in air. The second, a precipitation stage, consists of soaking the material for 4 hr. at 450 F.

Alclad 75S sheet can be heat treated over the temperature range of 860 to 930 F. This broad heat-treating temperature range permits Alclad 75S sheet to be heat treated in the same furnace load with 24S. A lower maximum temperature of 880 F. is recommended for 75S extrusions. The soaking periods normally used for 24S products have been found satisfactory for the new alloy. However, since the resistance to corrosion of Alclad 75S-T is less affected by diffusion than that of Alclad 24S-T, a greater number of reheat treatments are permissible.



Rolling an experimental aluminum alloy ingot into sheet on a pilot-size rolling mill at the Aluminum Research Laboratories.

Rapid quenching in cold water, such as now specified for 24S, is recommended for 75S. The mild quenches which are sometimes used for Alclad 24S-T have no effect on the resistance to corrosion of Alclad 75S-T, but some loss of strength may occur.

Products of 75S alloy age harden at room temperature subsequent to solution heat treatment. The initial yield and tensile strengths of 75S are somewhat lower than those of 24S and these low values hold for approximately 1 hr. After 2 hr., the increase is 2,000 to 3,000 p.s.i. in both yield and tensile strengths —about the same increase that takes place in about 1 hr. or less with 24S.

Unlike 24S which attains maximum strengths after 1 to 4 days aging at room temperature, 75S continues to harden for an indefinite period. As in the case of 24S, room temperature aging of 75S can be retarded by storage at sub-normal temperatures. At 32 F. no appreciable increase in yield strength will occur for a period of 24 hr., whereas, at 0 F. aging is prevented for at least a week. Rapid cooling to storage temperature is of course desirable.

An elevated temperature precipitation treatment (artificial aging) is required in order to produce the fully heat-treated temper. The recommended treatment is 20 to 24 hr. at 250 F. Maximum strengths will be attained if the artificial aging is started within 2 hr. after quenching or else delayed for two days.

Formability

The formability of Alclad 75S sheet has been appraised by laboratory bend tests as a guide for shop forming tests. Standard shop practices will be established through trial and error in the shop itself, and it is suggested that those who plan to use 75S material base their design demands on trial forming work done in their own shops.

The formability of Alclad 75S-O is similar to that of Alclad 24S-O so that, in general, only minor changes are required to adapt tooling designed for

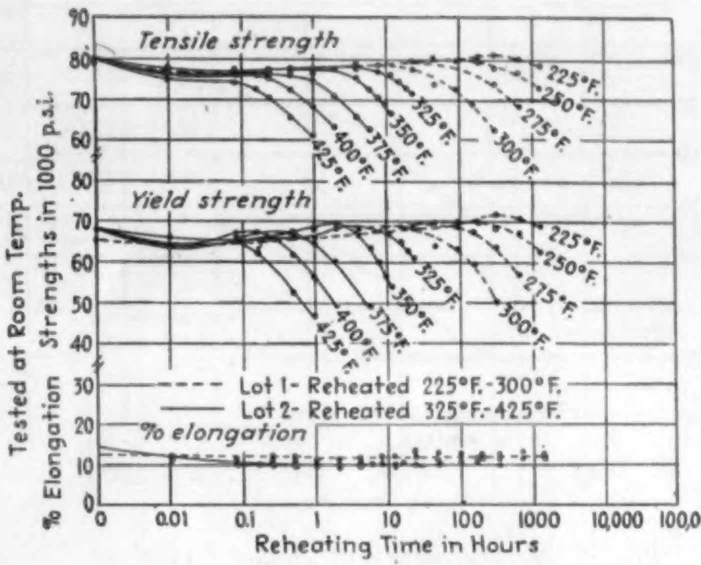


Fig. 1. Room temperature aging of 24S and 75S.

Alclad 24S-O sheet to the use of Alclad 75S-O sheet. As a result of a slightly higher yield strength in Alclad 75S-O as compared with Alclad 24S-O, slightly higher pressures may be required in rubber pad hydraulic press work. Certain difficulties may also be encountered in hand hammering.

The strengths of freshly quenched Alclad 75S sheet suggest the use of material in this condition for many forming operations. The strengths show no increase for at least 1 hr. and are slightly lower than comparable freshly quenched Alclad 24S. Under these conditions more severe forming operations are possible than with Alclad 24S. In difficult forming operations requiring several softening treatments, it is recommended that a solution heat treatment be used for the final softening operation. This will avoid the distortion usually encountered in the heat treatment of formed parts and eliminate difficult straightening operations.

In general, Alclad 75S-T sheet is less workable than Alclad 24S-T sheet and this is reflected in certain changes in working procedure. The bend radii have to be increased by at least 1T and posibly 2T over

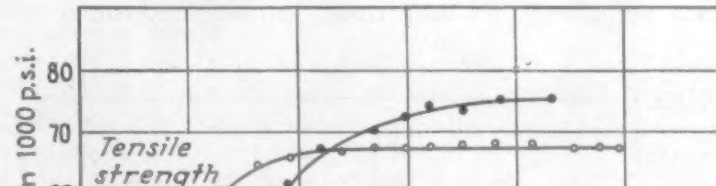


Fig. 2. Reheating of Alclad 75S-T at 225 to 425 F.

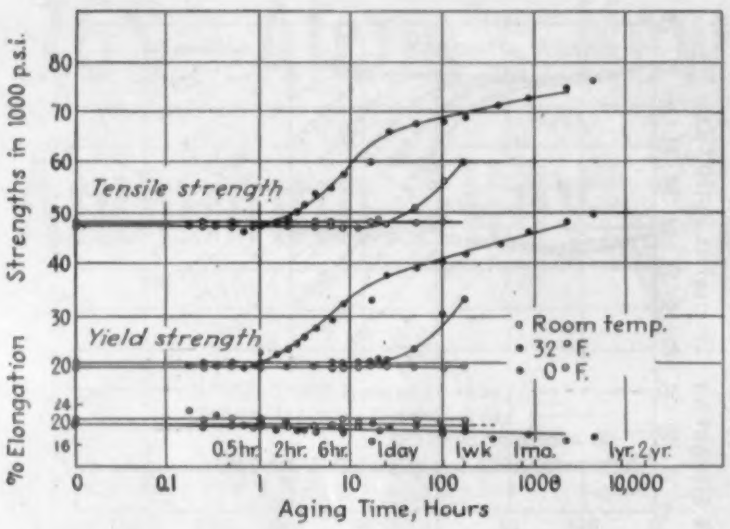


Fig. 3. Natural aging of Alclad 75S sheet.

those used for Alclad 24S-T. It should also be kept in mind that a different allowance for springback is required for Alclad 75S-T than for Alclad 24S-T.

Some study has been made of the effect of reheating in connection with the hot forming of 75S-T products. It has been found that a marked improvement in workability is obtained at 250 F. This does not alter the room temperature strengths. The reheating of the alloy has no adverse effect on its resistance to corrosion.

The dimpling of Alclad 75S-T sheet for flush riveting in thickness of 0.032 in. and under can usually be accomplished with tools now used for Alclad 24S-T. However, the dimpling of heavier Alclad 75S-T sheet requires changes from current practices but encouraging results are being obtained by various aircraft companies through the use of special tools.

Resistance to Corrosion

The accurate evaluation of the resistance of a new alloy to corrosion and stress corrosion is a tedious proposition as long times are required to properly appraise exposure tests in natural environments. Results from a large number of accelerated corrosion tests on alloy 75S and from limited exposures to natural environments lead to the following conclusions.

Alclad 75S-T sheet has a resistance to corrosion similar to that of Alclad 24S-T. The resistance to corrosion of Alclad 75S-T sheet is less affected by slower quenching rates and diffusion, particularly in the thinner gages. The chances of stress corrosion cracking of Alclad 75S-T sheet in service are very remote because of the electrolytic protection afforded by the alclad coating. None has been observed in tests to date, which have included one year sea coast exposures of highly stressed, plastically deformed samples.

Extrusions of 75S-T have a resistance to general corrosion and stress corrosion cracking comparable to that of 24S-T extrusions. Samples of extruded 75S-T rod have not stress cracked in 2 yr.'s outdoor exposure at New Kensington, Pa., to alternate immersion in sea salt solution, although they were stressed longitudinally in direct tension to about 60,000 p.s.i., which is three-fourths of their strength. However, as with other materials, the resistance to stress corrosion cracking is higher when the material is stressed in a longitudinal direction than when it is stressed in a transverse direction. Therefore it is recommended, as for 24S, that fabrication and assembly procedures which result in the lowest possible residual tensile stresses on exposed surfaces be followed.

Protective measures generally found satisfactory for Alclad 24S-T sheet and 24S-T extrusions should also be satisfactory for comparable products of 75S.

Jointing

The bearing strength of 75S is sufficiently high to permit the use of the new high shear design values recently authorized by the Army Air Forces for A17S-T, 17S-T and 24S-T rivets. It should be pointed out that all of the rivets mentioned will be electrolytically protected by Alclad 75S-T sheet or 75S-T extrusions.

Alclad 75S-T sheet can be satisfactorily spot welded with the equipment ordinarily used in the aircraft industry. However, the new alloy requires more tip

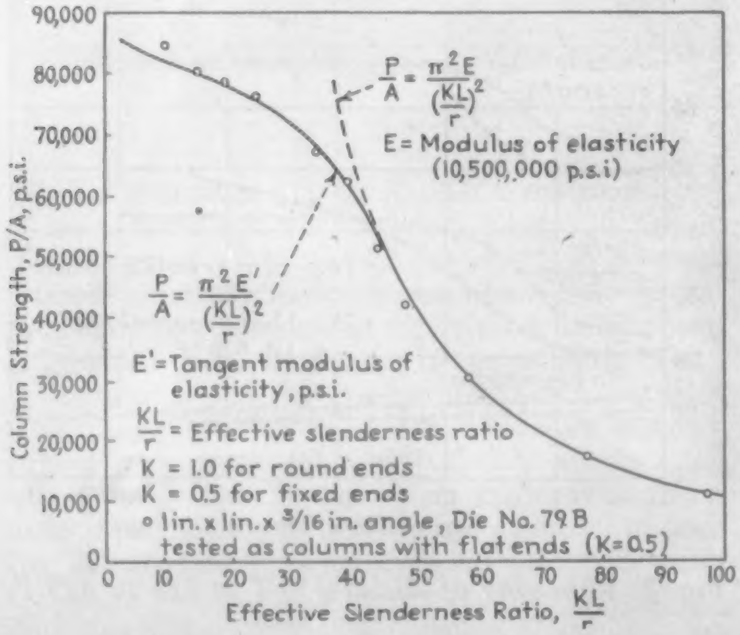


Fig. 4. Column strength of extruded 75S-T.

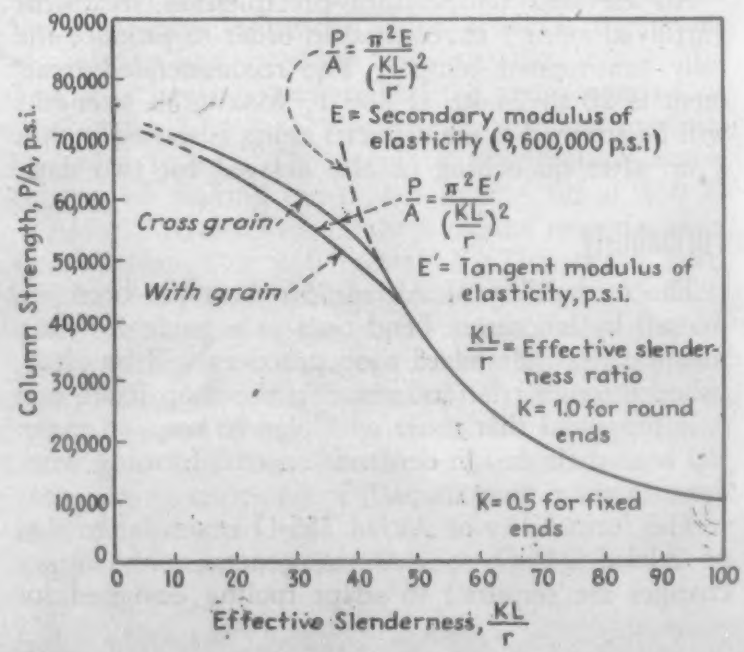


Fig. 5. Column strength of Alclad 75S-T sheet.

Table of Mechanical Properties of 75S Alloy

Property	Sheet				Extrusions	
	Alclad 75S-O	Alclad 75S-W	Alclad 75S-T 0.016-0.039 in. thick	Alclad 75S-T 0.040-0.249 in. thick	75S-O	75S-T
Tensile Str., p.s.i.						
Typical	32,000[1]	46,000	76,000	77,000	40,000	88,000
Minimum	36,000	—	70,000	72,000	40,000[1]	78,000
Yield Str. (0.2% offset), p.s.i.						
Typical	15,000	20,000	66,000	67,000	20,000	80,000
Minimum	—	—	60,000	62,000	—	70,000
Elongation (% in 2 in.)						
Typical	16	20	10	12	12	10
Minimum	10	—	7	8	6	6
Young's Mod. of El., p.s.i.	—	—	10,400,000[2]	10,400,000[2]	—	10,400,000
	—	—	9,600,000[3]	9,600,000[3]	—	—
Shear Str., p.s.i.	—	—	46,000	46,000	—	47,000
Hardness, Brinell	—	—	—	—	—	145-160
Rockwell B	—	—	—	—	—	85-95
Endurance Limit	—	—	—	—	—	22,500
Bearing Values[4] ÷						
Edge Distance, 1.5d — Bearing Str.	—		1.5 T.S.			1.3
Edge Distance, 1.5d — Bearing Yld. Str.	—		1.4 T.Y.S.			1.3
Edge Distance, 2d — Bearing Str.	—		1.9 T.S.			1.6
Edge Distance, 2d — Bearing Yld. Str.	—		1.6 T.Y.S.			1.4
Approximate Relations Among Tensile and Compressive Properties with and across the grain.	1. The longitudinal and transverse tensile strength are equal to each other 2. The longitudinal compressive yield strength is equal to the transverse yield strength 3. The longitudinal tensile yield strength is 5% greater than the transverse tensile yield strength 4. The transverse compressive yield strength is 5% greater than the transverse tensile yield strength				The compressive yield strength is equal to the tensile yield strength	
Column Strength	The column strength of 75S-T extrusions as determined in tests of a typical shape is indicated in one of the charts attached. It will be noted that the test data agree very well with the computed tangent modulus column curve. The column strength of Alclad 75S-T sheet was calculated on the same basis from the typical compression stress-strain curves. A calculated curve is presented because column tests of flat specimens of Alclad sheet do not result in data representative of aircraft structure.					

[1] Maximum [2] Primary [3] Secondary [4] d=diam. of rivet or hole

pressure, flatter tip contour, and a somewhat narrower range of machine settings than does Alclad 24S-T. Steel wool or wire brush may be used for mechanical cleaning prior to welding. If chemical cleaning is used, a nitric acid hydrofluoric acid cleaning solution is recommended. Strength requirements for Alclad 24S-T spot welds can, under proper conditions, be met with Alclad 75S-T spot welds.

Corrosion tests of spot welded bare and Alclad 75S-T have not yet been completed. Based on earlier experiments, the spot welding of Alclad 75S-T sheet 0.032 in. and thicker is expected to be just as satisfactory as it has been on Alclad 24S-T. It is indicated that the jointing of two bare 75S-T parts by spot welding will not be suitable for aircraft use because of poor resistance to corrosion.

Miscellaneous products of 75S such as plain sheet and plate, wire, rod, bar and tubing are still in process of evaluation. It is expected that these will be in commercial production within a short time.

R301—Reynolds' New High Strength Aluminum Alloy

by T. L. FRITZLEN AND L. F. MONDOLFO

Chief Research Metallurgist and Research Metallurgist, respectively, Reynolds Research Institute of Reynolds Metals Co., New York

R301 IS A NEW CLAD material consisting of a high-strength core alloy, clad with a medium-strength corrosion-resistant alloy. Its general attributes are those of a high-strength light-weight material with corrosion-resistance comparable to that of pure aluminum but with mechanical properties superior to those of conventional pure-aluminum-clad metals. It is also easy to fabricate, can be heat treated, and introduces no contamination in the usual scrap-handling systems.

Composition and Structure. The chemical composition of the material is reported in Table I.

Table I. Nominal Composition of R301

Element	*Core, %*	*Cladding, %*
Silicon	1.0	0.7
Copper	4.5	0.4 max.
Manganese	0.8	0.5
Magnesium	0.4	1.0
Iron	1.0 max.	0.7 max.
Chromium	0.1 max.	0.35 max.
Zinc	0.25 max.	0.2 max.
Other Elements (each)	0.05 max.	0.05 max.
Other Elements (total)	0.15 max.	0.15 max.

The values given for iron, chromium, zinc and copper in the cladding are the maximum permissible according to AAF specification No. 11356. Manufacturing limits, however, have been set much lower, in order to insure the best properties of the alloy. As it can be seen, the composition of R301 is similar to that of most other high-strength aluminum alloys now used extensively. This is an advantage because if scrap or clippings of R301 are inadvertently mixed with other alloys, the remelted material will still have a composition that can easily be utilized.

The normal microconstituents of the alloy are shown in Figs. 1 and 2, which represent respectively the core and cladding material, as cast. The constituents are shown in the as-cast condition, because after rolling and heat treatment it is much more difficult and sometimes impossible to identify them.

Cladding Thickness. The cladding thickness varies with the gage as reported in Table II.

Table II. Nominal Thickness of Cladding for Various Gages

Gage	*% Cladding on Each Face*
0.024 in. or less	10
0.025 in. to 0.039 in.	7.5
0.040 in. to 0.101 in.	5
0.102 in. and heavier	2.5

ENGINEERING ACHIEVEMENTS

In the race to develop and produce light metals with a combination of extra-high-strength and good corrosion resistance for the urgent needs of our swelling aircraft program, the Reynolds Metals Co. was up front from the moment it became a large-scale producer of aluminum and its alloys. One of the results was R-301, a new composite aluminum alloy offering a combination of mechanical and surface properties not available in any other metal. In publishing this first complete technical description of the composition, properties and treatment of this bright-futured material we also hail it as one of the war's leading engineering achievements.

—*The Editors*

Roll-forming of R301 sheet.

The material is produced in 3 tempers, designated as follows:

Annealed—O
Solution-treated—W
Solution-treated and aged—T

The typical microstructures of the 3 tempers are shown in Figs. 3 to 10.

Mechanical Properties

The typical properties of the alloy are reported in Table III. The mechanical properties at high temperture have not yet been determined, as the alloy is not especially designated for use at elevated temperatures. Preliminary tests, however, have shown that R301 at elevated temperatures has mechanical properties at least as good as other high strength aluminum alloys of the same type. There are indications that R301 may be slightly superior. More tests are in progress and will be published as soon as possible.

Guaranteed Properties. The minimum mechanical properties, as covered by specifications are reported in Table IV.

Table IV. Guaranteed Minimum Tensile Properties Applicable to Material in the Specified Temper.

Temper	*Thickness*	*Tensile Str., p.s.i.*	*0.2% Yield Str. in p.s.i.*	*Elongation, % in 2 in.*
Annealed-O	All	30,000*	——	16.0
Solution treated-W	.039" & under	56,000	37,000	14.0
	.040" & over	57,000	37,000	15.0
Solution treated and aged-T	.039" & under	63,000	56,000	7.0
	.040" & over	64,000	57,000	8.0
Tensile properties applicable to reheat-treated material and to material annealed and subsequently heat treated.				
Solution treated-W	All	55,000	35,000	15.0
Solution treated and aged-T	All	62,000	54,000	8.0

*Maximum

Heat Treatment

The heat treatment practice for R301 is similar to that of other alloys; that is, the alloy can be annealed, solution-treated and precipitation-treated.

Annealing. The annealing practice is as follows:

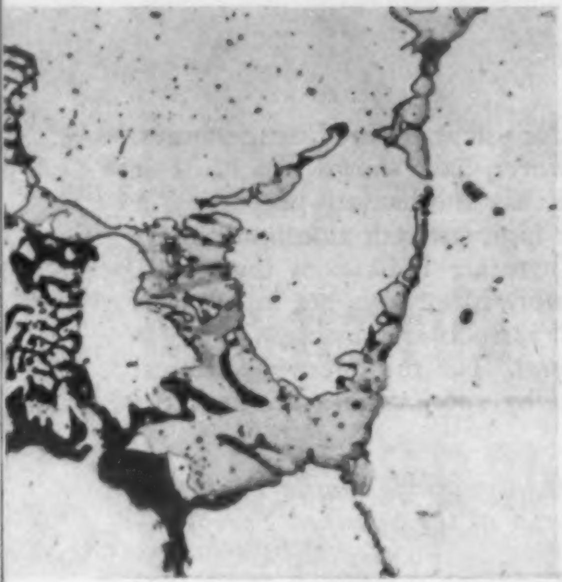
(1) To relieve hardening due to cold work,— 2 hrs. at 650 ± 10 F.

(2) To relieve hardening due to heat treatment,— 2 hrs. at 750 ± 10 F., followed by cooling at a rate not in excess of 50 F. per hr. to 600 F.

Table III. Typical Properties of R301

Property	*Temper and Gage* R301-O All gages	R301-W 0.039 and lighter	R301-W 0.040 and heavier	R301-T 0.039 and lighter	R301-T 0.040 and heavier
Tensile strength, p.s.i.	25,000	59,000	61,000	66,000	69,000
0.2% yield strength, p.s.i.	10,000	39,000	41,000	60,000	61,000
Elongation, % in 2 in.	22	19	20	9	9
Rockwell E hardness	45-50	100	95	105	100
Compressive yield strength, p.s.i.	——	——	——	62,000	62,000
Shear strength, p.s.i.	——	——	——	43,000	43,000
Endurance limit, p.s.i.	——	——	——	12,500	12,500
Mod. of Elasticity, p.s.i.	10,300,000	10,300,000	10,300,000	10,300,000	10,300,000
Density, lbs. / cu. in.	0.101	0.101	0.101	0.101	0.101

Bearing Strength, R301-T		
Edge Distance	1.5D	2D
Ultimate strength, p.s.i.	105,000	139,000
Yield strength, p.s.i.	70,000	93,000



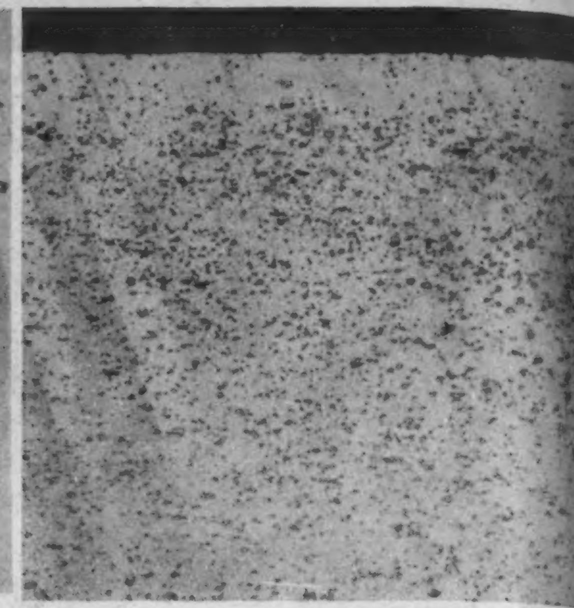


Fig. 1. (Left) Core material, 500X, etched with H_2SO_4 20%, 70 C., 30 sec. The black constituent in the form of Chinese script is AlFeMnSi, the light masses are $CuAl_2$. The small black veins inside the $CuAl_2$ masses are the eutectic Al-$CuAl_2$-Si. The gray needles inside $CuAl_2$ are AlCuMgSi. Fig. 2. (Center) Cladding material, 500X, not etched. The black constituent is Mg_2Si, the gray constituent in the form of Chinese script is AlFeMnSi. Fig. 3. (Right) R301-O, 75X, not etched. Large amounts of precipitated constituents are visible in the core.

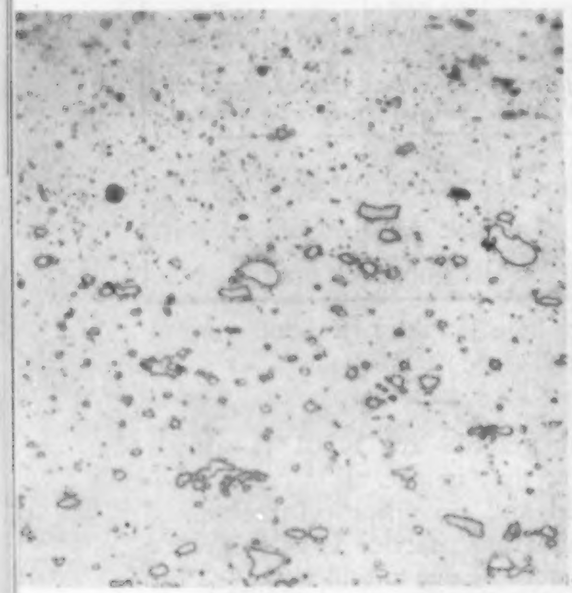
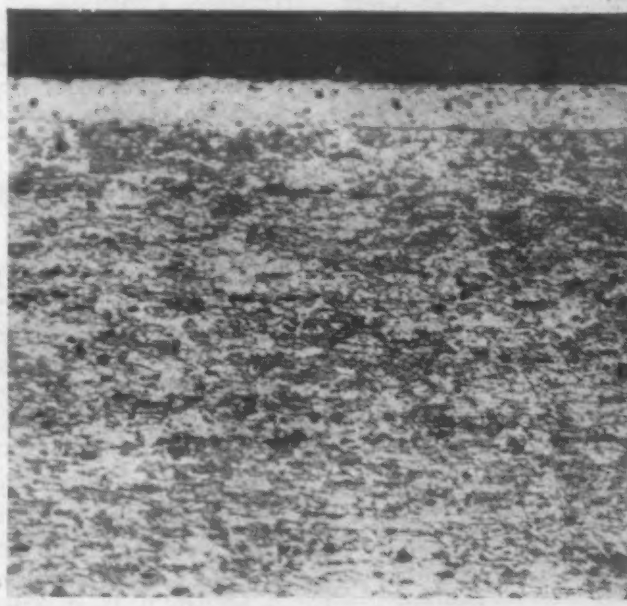
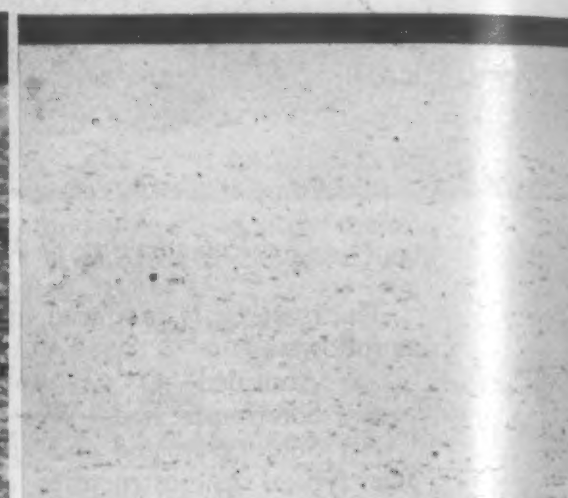




Fig. 4. (Left) R301-O, 500X, not etched. The black constituent in the cladding (top) is Mg_2Si, the gray constituent both in the core and the cladding is AlFeMnSi. In the core (bottom) few particles of a lighter constituent, which is $CuAl_2$, are visible. Fig. 5. (Center) R301-O, 75X, etched with Keller's etch. Grain boundaries visible in the core (bottom). Fig. 6. (Right) R301-W, 75X, not etched. The soluble constituents are mostly dissolved and cannot be seen. Only AlFeMnSi (gray) and some Mg_2Si (black) in the cladding are visible.

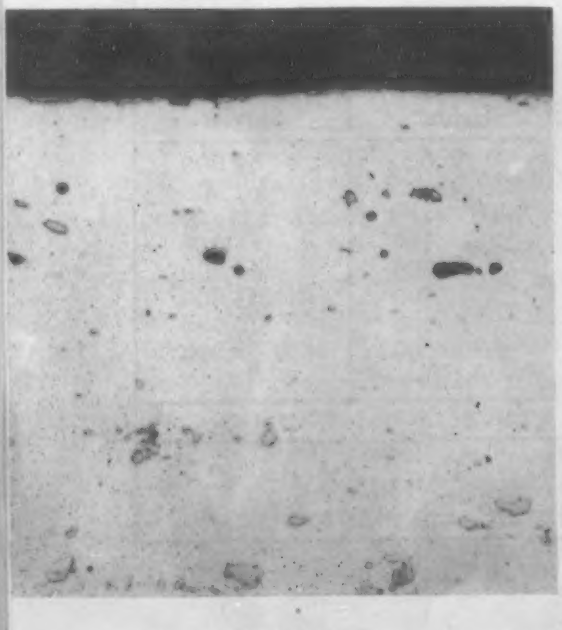
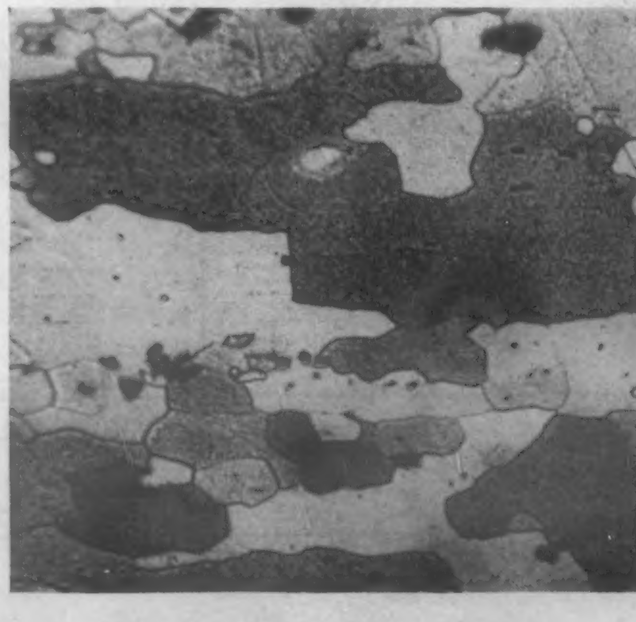
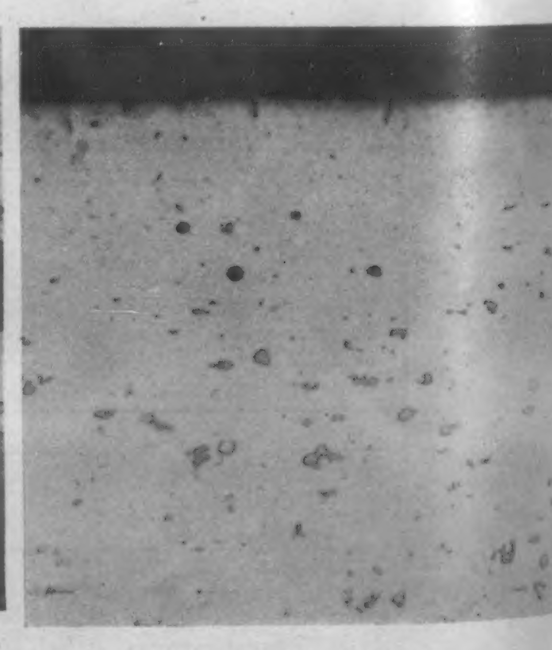




Fig. 7. (Left) R301-W, core, 500X, not etched. The dark gray constituent is AlFeMnSi. The lighter gray constituent rounded is $CuAl_2$. Fig. 8. (Center) R301-W, core, 500X, etched with Keller's etch. High contrast between grains. Absence of precipitate at grain boundaries. Fig. 9. (Right) R301-T, 500X, not etched. No difference can be noticed from W material without etching.

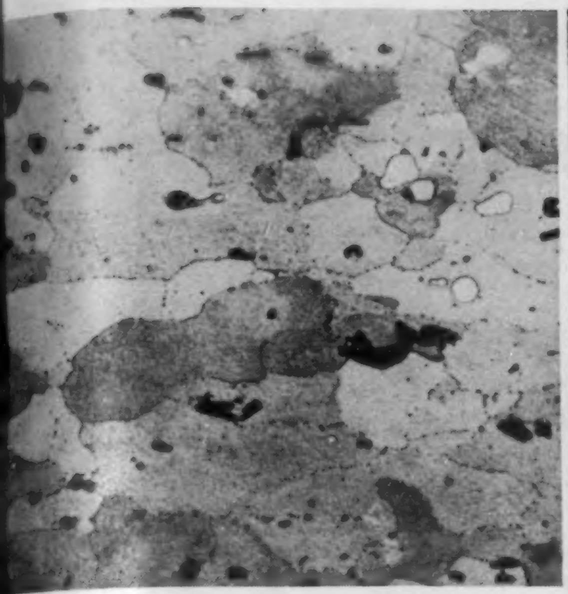
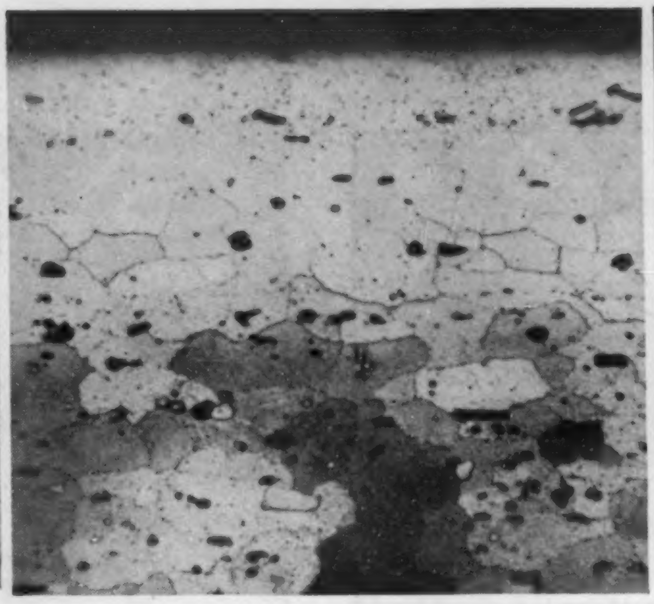
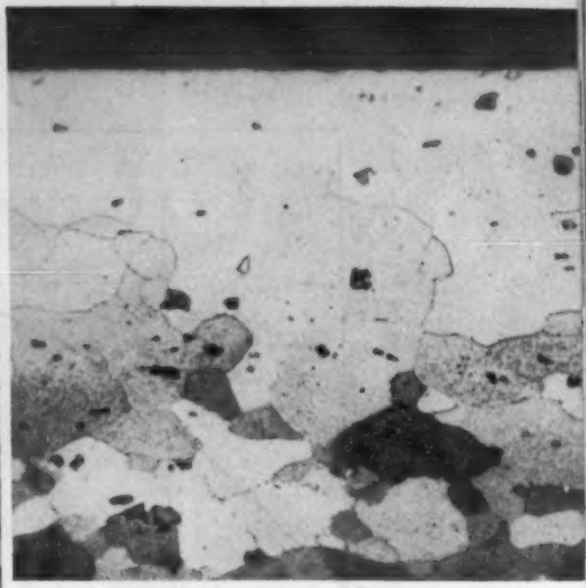




Fig. 10. (Left) R301-T, 500X, etched with Keller's etch. Less contrast between grains than in W material, presence of precipitate (small points) at grain boundaries. Fig. 11. (Center) An 0.025 gage properly solution treated, 500X etched with Keller's etch. Normal amount of diffusion, as revealed by the grain boundaries extending only a short distance into the cladding. Fig. 12. (Right) Same material, held 30 min. at temperature. 500X, etched with Keller's etch. Slightly higher diffusion.

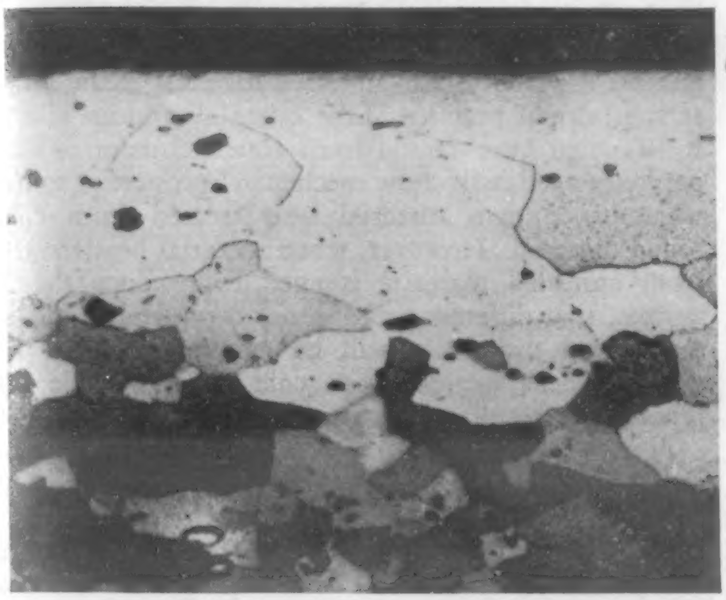
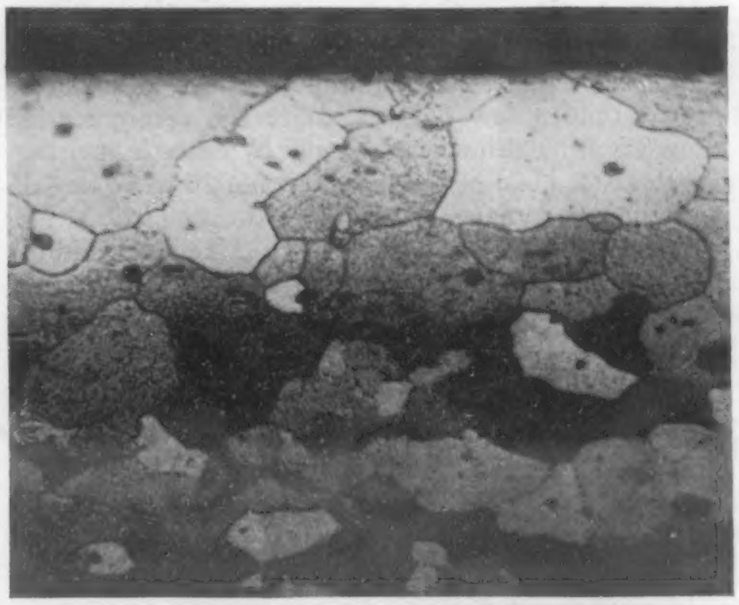



Fig. 13. (Right) Same material, held 40 min. at temperature. 500X, etched with Keller's etch. The copper begins to reach the surface, as shown by the grain boundaries extending all the way through the cladding. Fig. 14. (Left) Same material held 50 min. at temperature. 500X, etched with Keller's etch. Diffusion well progressed.

Solution Treatment and Diffusion. The solution treatment time is limited by the need to avoid excessive diffusion of the copper through the cladding, which will produce susceptibility to intergranular corrosion. Figs. 11 to 14 show the effect of increasing solution treatment times on the diffusion in 0.025 in. material. Fig. 15 shows the diffusion curve on R301. Solution treatment times have been set as reported in Table V.

Table V. Recommended Solution Treatment Times and Allowable Reheat Treatments.

Gage, in.	*Time at temperature in minutes*	*Allowable reheat treatments*
0.032 & less	10	none
0.033 to 0.063	15	1
0.064 to 0.101	20	2
0.102 to 0.125	30	2
0.125 to 0.250	30	3
0.250 & heavier	60	3

The first heat treatment of material procured in the annealed temper is not a reheat treatment. Insufficient time, by not allowing complete solution of the copper in the core, will produce lower mechanical properties. Fig. 16 shows the microstructure of improperly solution-treated material.

Micro-examination has established the lowest melting eutectic in the alloy as the eutectic Al-$CuAl_2$-Si, with a melting point of 977 F. Figs. 17 to 20 show the microstructure of material heat treated respectively at 980 F.—990 F.—1000 F.

In Fig. 21, which shows the effect of increasing heat treatment temperatures on the mechanical properties, it can be seen that the amount of melting present in the material heat treated at 980 F. does not reduce the mechanical properties appreciably, even in the lighter gages which are more sensitive to defects.

The recommended heat treatment temperature is 940 F. ± 10 F. This temperature has been chosen as the one which will reduce to a minimum diffusion of

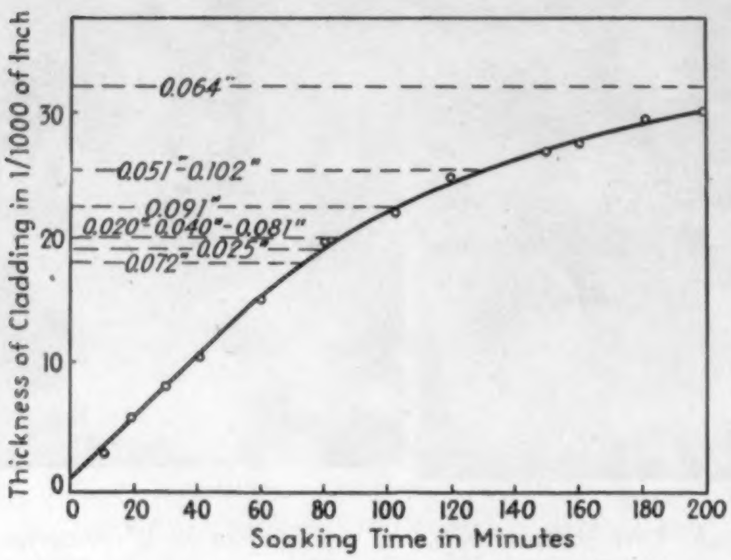


Fig. 15. Effect of soaking time on diffusion of copper into the cladding.

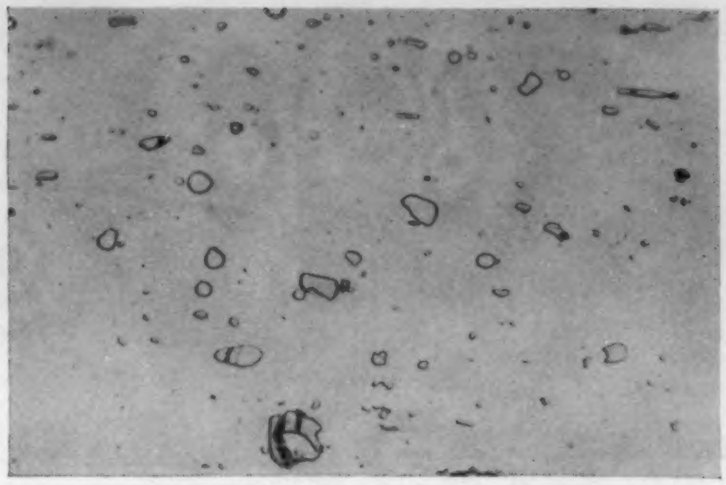


Fig. 16. A 0.102 gage material, solution treated 10 min., 500X, not etched. A large amount of $CuAl_2$ not dissolved is visible in the form of rounded, relieved particles.

the copper into the cladding and distortion, without reducing appreciably the mechanical properties. An added advantage of this temperature of heat treatment is the fact that the control does not need to be too close. Other strong aluminum alloys, when overheated only a few degrees above the recommended limits, will be ruined irreparably by eutectic melting. R301 instead can be overheated some 20 to 30 deg. F. without any damage.

High-temperature deterioration. Like other aluminum alloys, R301 is susceptible to high temperature deterioration when heat treated in atmospheres containing water vapor or sulfur. This high temperature deterioration, if not excessive, does not affect the mechanical properties appreciably. In more severe cases the material blisters and the mechanical properties are reduced. Figs. 22 and 23 show respectively a small and large amount of high temperature deterioration.

Proper care of the heat treatment furnaces will prevent the development of high temperature deterioration. Compounds which are commonly recommended for preventing high temperature deterioration in other aluminum alloys are equally effective in the heat treatment of R301.

Solution treatment of annealed material. The heat treatment practices for annealed material is the same as the normal practice. Like other aluminum alloys, R301 when heat treated from annealed material and naturally aged, will show mechanical properties somewhat lower than material heat treated from cold rolled material. However, when material heat treated from annealed material is aged to produce the T temper, that difference disappears completely and the mechanical properties will be as high as those of material heat treated from cold rolled. Table VI reports the results of experiments run on all gages.

Natural Aging. R301 ages naturally at a rapid rate in the first 4-5 hrs. and after 24 hrs. has reached about 90% of the final mechanical properties. After 24 hrs. the aging progresses slowly for about 10 days more, after which the mechanical properties become stable. Fig. 24 shows the natural aging curve for R301 over a period of one year. The mechanical properties

Table VI. Mechanical Properties of R301 Heat Treated from the Annealed Temper.

	W Temper—Aged 4 days at room temp.				T Temper—Aged 6 hrs. at 350 F.			
Gage	*Number of tests*	*Yield*	*Tensile*	*Elong.*	*Number of tests*	*Yield*	*Tensile*	*Elong.*
0.020	20	34.5	56.9	20.2	11	56.8	65.3	8.9
0.025	26	36.6	59.3	20.8	16	59.3	67.2	8.7
0.032	24	36.5	58.6	20.5	14	59.3	67.1	8.9
Average*	*70	35.9	58.3	20.5	41	58.5	66.5	8.8
0.040	27	35.5	50.3	20.7	44	61.5	68.6	8.4
0.051	25	37.2	60.8	20.8	39	61.7	68.4	9.–
0.064	12	36.8	61.1	21.4	19	63.1	69.2	9.3
0.081	18	36.2	59.7	21.0	31	60.9	67.6	9.–
0.091	6	36.5	59.7	20.3	10	61.–	67.6	9.–
0.102	8	39.3	63.1	19.9	16	65.1	71.3	8.9
0.125	15	38.5	62.6	21.1	28	64.–	70.–	9.3
0.156	12	37.7	61.7	20.2	19	63.5	70.1	9.–
0.188	6	37.6	62.–	21.3	10	63.2	69.8	9.3
0.250	—	—	—	—	18	65.–	69.–	9.8
Average*	129	37.2	61.2	20.7	234	62.9	69.2	9.1

*These averages have been reported to facilitate comparison with values reported for material heat treated from the cold-rolled condition and with the specifications. It will be noticed that the results tabulated include a few defective specimens which in production tests would have been rejected.

of R301 naturally aged are comparable to those of other strong aluminum alloys, however, the best mechanical properties are obtained by artificial aging.

Artificial Aging. R301 can be artificially aged over a wide range of temperatures and times. Fig. 25 shows the effect of the aging temperature and time on the mechanical properties of the alloy. Table VII shows the times recommended for each temperature.

Table VII. Aging Times Recommended for Each Temperature.

Temperature °F	*Time*
320 ± 5	18 hr. ± 1 hr.
330 ± 5	12 hr. ± 1 hr.
340 ± 5	8 hr. ± 1 hr.
350 ± 5	6 hr. ± 30 min.
360 ± 5	5 hr. ± 30 min.
375 ± 5	4 hr. ± 15 min.

Two aging treatments are particularly recommended: (1) aging 18 hr. at 320 F. when some forming has to be done after aging; (2) 6 hr. at 350 F. ± 5 F. when no more forming has to be done. If the aging furnaces cannot be controlled within ± 5 F. a treatment at 340 F. ± 10 F. for 8 hr. is recommended.

The aging can be done at any time after quenching, no waiting time is required between quenching and aging. As for other aluminum alloys, a long delay between quenching and aging lowers the mechanical properties of R301-T but even with several months delay, the material will exceed specifications.

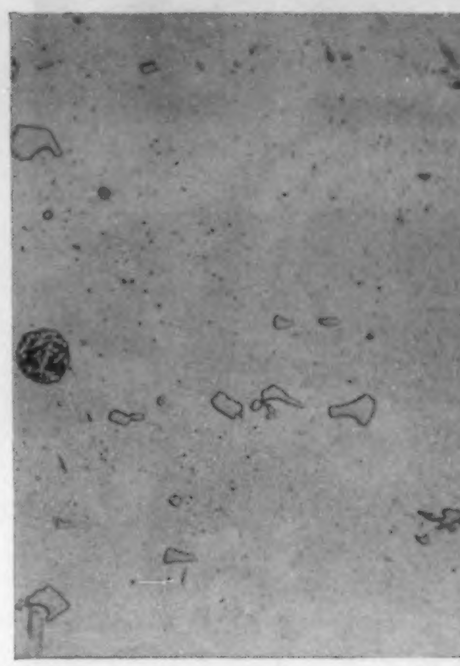
Preliminary experiments have shown that by increasing the aging time the decrease of mechanical properties caused by an excessive delayed aging can be minimized. Research is in progress to determine the aging treatments required by material which has been stored for a long time in the W temper.

Forming

One of the properties which have induced some manufacturers of airplanes to rate R301 as the best strong alloy for airplane parts is its formability. We believe that R301 in the O temper forms better than any other high strength alloy on the market. R301 freshly quenched forms about as well as most other strong alloys in the annealed temper.

R301 in the W temper has also good formability and in many cases can be used to replace other high strength alloys which must be formed in the O temper. This is a great advantage because the only processing required by R301 in the W temper to reach maximum properties is an aging treatment at low temperature, without quenching. Such a treatment will not produce any distortion in the formed parts, as compared with the unavoidable distortion caused by heat treatment at elevated temperatures, followed by quenching, as required by material formed in the O temper. Fig. 26 shows some parts formed from R301 in the W temper.

R301 in the T temper forms approximately as well as other strong alloys in the T temper. Although it is not possible to give a definite rule as to which temper should be used for every forming, the following suggestions are inserted here as a guide in the



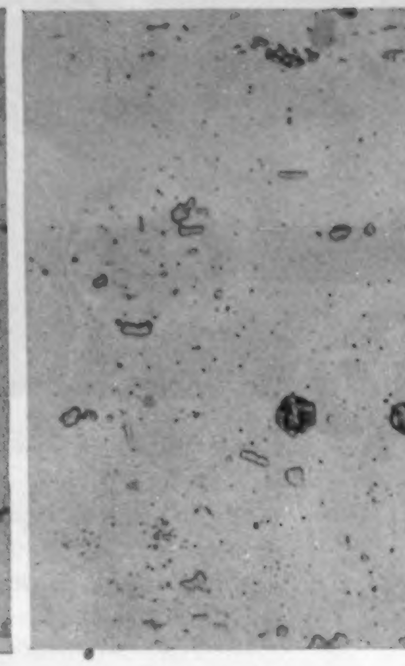
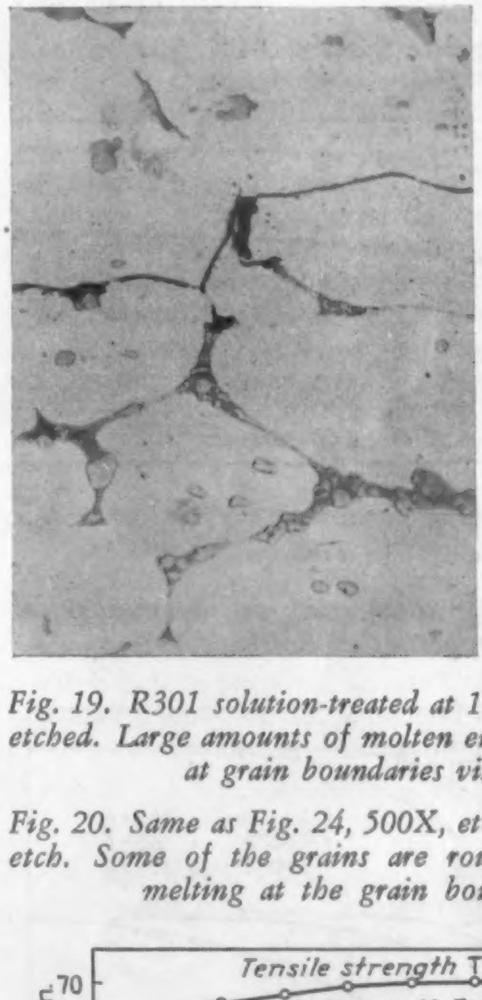


Fig. 17. R301 solution-treated at 980 F., 500X, not etched. A small rosette of eutectic Al-CuAl$_2$-Si is visible.

Fig. 18. R301 solution treated at 990 F., 500X, not etched. Few rosettes of eutectic and a small intergranular crack are visible.



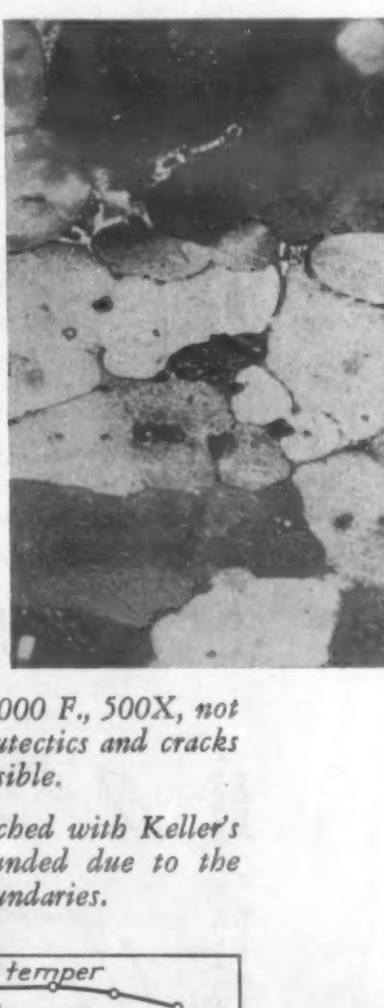


Fig. 19. R301 solution-treated at 1000 F., 500X, not etched. Large amounts of molten eutectics and cracks at grain boundaries visible.

Fig. 20. Same as Fig. 24, 500X, etched with Keller's etch. Some of the grains are rounded due to the melting at the grain boundaries.

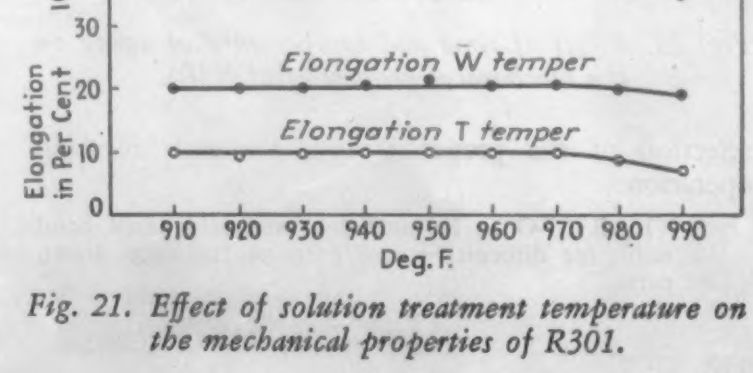
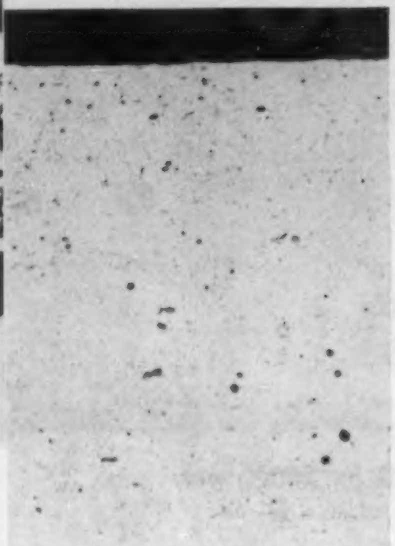


Fig. 21. Effect of solution treatment temperature on the mechanical properties of R301.



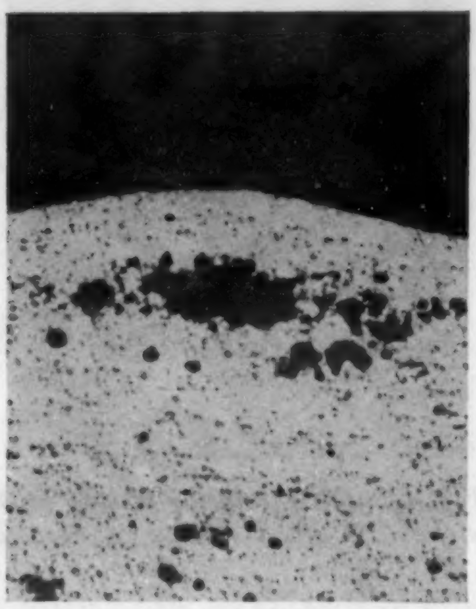


Fig. 22. Small amount of high temperature deterioration, as shown by the small black spots. 75X, not etched.

Fig. 23. Section through a blister caused by high temperature deterioration. 50X, not etched.

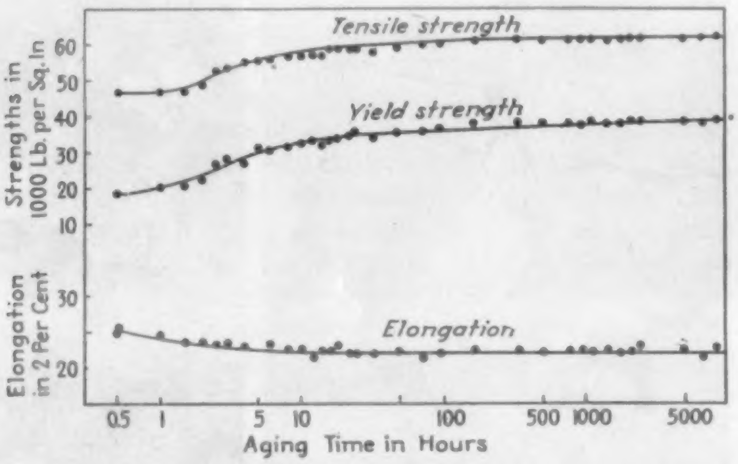


Fig. 24. Effect of natural aging on the mechanical properties of R301.

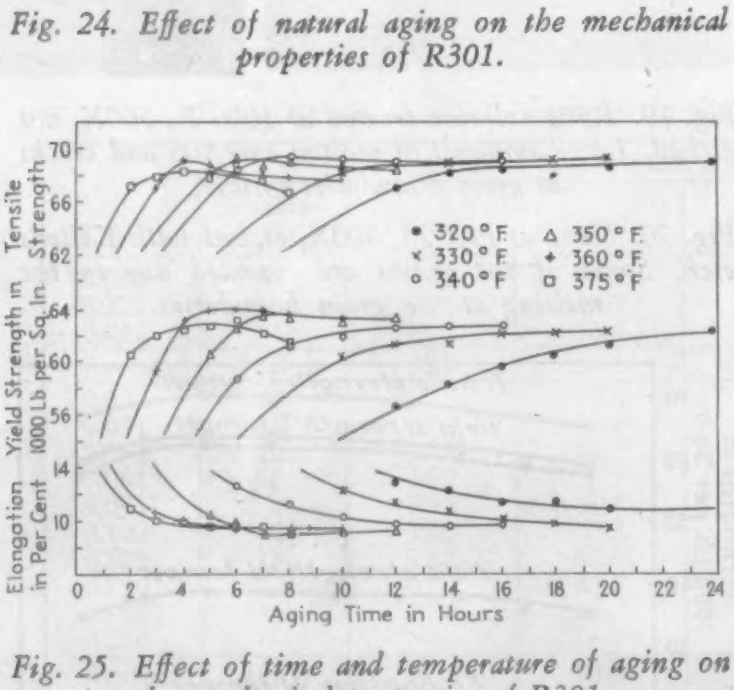


Fig. 25. Effect of time and temperature of aging on the mechanical properties of R301.

selection of the proper temper for each forming operation:

(1) R301-O to be used for extremely small bend radii, for difficult formed parts or for deep drawn parts.

(2) R301 freshly quenched to be used for small radii parts, for drawn parts not severe as these requiring the O temper or for parts requiring severe stretching.

(3) R301-W to be used for formed parts where extremely small radii are not required or for parts requiring moderate stretching.

(4) R301-T to be used for those parts requiring liberal radii and very little drawing or stretching.

Bend Radii. In Table VIII are reported the bend radii recommended for safe forming of R301. In view of the somewhat limited experiences with the alloy, the bend radii recommended are conservative. It is expected that with proper care, smaller radii can be safely used.

Table VIII. Bend Diameter Recommended for 180° and 90° Bends in Terms of Thickness, T

Bend	*Gage, in.*	*O Temper*	*W Temper*	*T Temper*
180 deg.	0.039 & lighter	0	3	4
	0.040 to 0.051	0	3	5
	0.052 to 0.128	0	3	6
	0.129 to 0.249	1	4	8
	0.250 to 0.500	2	5	10
90 deg.	up to 0.064	1 T	2 T	3½ T
	0.064 to 0.081	1 T	2 T	4 T
	0.082 to 0.125	1 T	3 T	4 T

Corrosion Resistance

The corrosion resistance of R301 is very high and compares favorably with that of other strong alloys in the market. Very little difference exists between the corrosion resistance of the two tempers W and T.

R301 in either temper is not susceptible to intergranular corrosion and the corrosion in all the tests has been found to be of the pitting type (Fig. 27). Even slow quench, as may be produced by quenching in boiling water or oil, does not impair the corrosion resistance of the alloy. Only when the alloy has been grossly mistreated, as when the heat treatment time has been protracted to 3 to 4 times the normal, so that the cladding is thoroughly diffused, light gages may show intergranular corrosion (Fig. 28).

The surface of R301 when exposed to corrosion without any protection, tends to darken. This darkening, however, is only superficial and does not impair at all the performance of the alloy. If the darkening is objectionable it may be avoided by anodizing or even by coating the parts with a very thin layer of transparent lacquer. Rubbing of the surface with a polish compound will remove the darkening.

Numerous tests, either by immersion or by salt spray exposure, have shown that R301 in either W or T temper is not susceptible to stress corrosion, nor that the corrosion is accelerated by stresses.

Electrolytic Potential. The potential of R301 as determined with a saturated calumel electrode against a 6% NaCl, 0.3% H_2O_2 solution, is reported in Table IX. The difference of potential between core and cladding in T material is lower than that of material in the W condition or clad with pure aluminum. However, extensive researches have shown that it is amply sufficient to protect electrolytically the core material and that no corrosion takes place in the core even on the edges, where the cladding does not cover the core.

Table IX. Electrolytic Potential of R301

Temper	Core, mv.	Cladding, mv.	Difference, mv.
R301-W	—65 ÷ 66	—83 ÷ 84	17—18
R301-T	—72 ÷ 74	—81 ÷ 83	8— 9

Accelerated Immersion and Salt Spray Tests. Extensive tests have been conducted using the standard $NaCl$-H_2O_2 solution. In Table X are reported some representative results of these tests.

Table X. Percent Loss of Mechanical Properties Caused by 6 hr. Immersion in the 6% NaCl-0.3% H_2O_2 Solution.

	W Temper			T Temper		
Gage	Tensile	Yield	Elong.	Tensile	Yield	Elong.
0.020	1.6	1.7	9.3	2.5	2.0	10.0
0.025	1.2	0.5	2.6	0.8	1.0	7.4
0.032	1.2	0.5	0	1.3	1.2	1.8
0.040	1.1	1.0	0.7	1.1	0.6	6.7
0.051	0.7	2.3	0	1.3	0	8.4
0.064	1.6	0.7	0	1.0	0.7	2.0

In order to confirm the data of the immersion tests, salt spray corrosion tests have been run. The results of these tests are in good agreement with the accelerated corrosion tests. In Table XI are reported some representative results on 0.040 gage.

Table XI. Percent Loss of Mechanical Properties Caused by Exposure to Salt Spray.

Temper	Exposure Time, hrs.	Tensile	Yield	Elongation
W	250	0.2	1.4	0
T	250	0.3	1.3	12.0
T	750	1.1	0.5	12.0

The data about corrosion in service are rather limited, in view of the short time that the alloy has been in use. However, the data available confirms the findings of the accelerated tests in that R301 has withstood any type of atmospheric corrosion.

Joining and Finishing

R301 can be welded like other aluminum alloys by the established methods of oxyacetylene, arc and spot or seam welding.

Torch Welding. R301 can be torch welded using either oxyacetylene or the oxyhydrogen flame. The welding technique is not different from that of other aluminum alloys. As with other high strength alloys, R301 welds are likely to crack if the proper practice is not observed. As filler material either the 5% Si alloy or R301 strip can be used.

When welding material in the W or T temper, which cannot be heat treated further, the 5% Si alloy may be more advantageous because the welding with it is slightly easier. If the material to be welded is in the O temper and is to be heat treated after welding, R301 strip should be used, so that the welds will have approximately the same strength of the material.

Material welded with either the 5% Si or R301 has a corrosion resistance approximately as good as the not welded alloy. The cladding around the weld protects the bare material in the weld, even in fairly heavy gages, so that no corrosion whatever will take place in the weld itself.

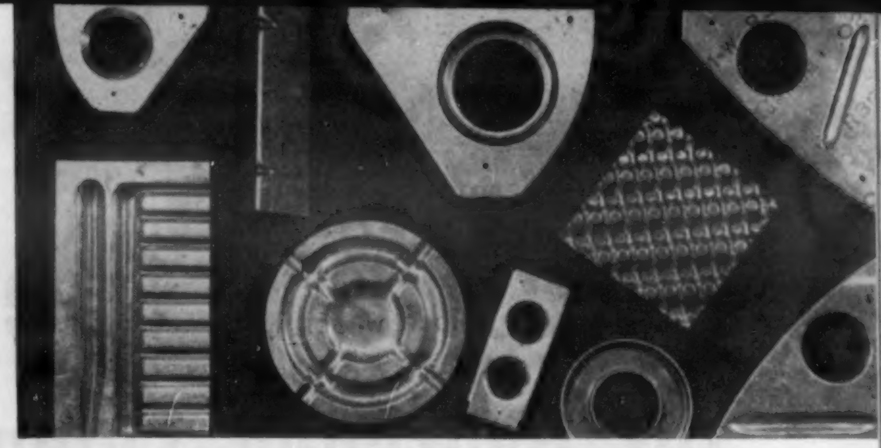


Fig. 26. Some typical parts formed from R301-W.

Spot Welding. R301 can be spot welded at least as easily as other aluminum alloys. The same machines and settings used for other high strength aluminum alloys will produce in R301 welds which will have somewhat greater strength and will have less tendency to crack. With special settings of the machines it is possible to produce welds in R301 with a much larger diameter than in other high strength alloys, and these larger spots will have increased strength. It is to be noticed that the zone affected by heat around the weld is very shallow and that, due to the similarity of composition of the core and cladding material, the weld itself is much more homogeneous than in welds of alloys clad with pure aluminum.

Riveting. R301 can be riveted with A17S, 17S, or 24S rivets and the strength of riveted joints in R301 is very high. The high strength found in riveted R301 is to be attributed to the behavior of the cladding which is not too soft to be squeezed out as happens in material clad with pure aluminum, nor too hard to shear the rivet as happens in some commercial bare alloys where riveted. Dimpling can be done on R301 also in the T temper.

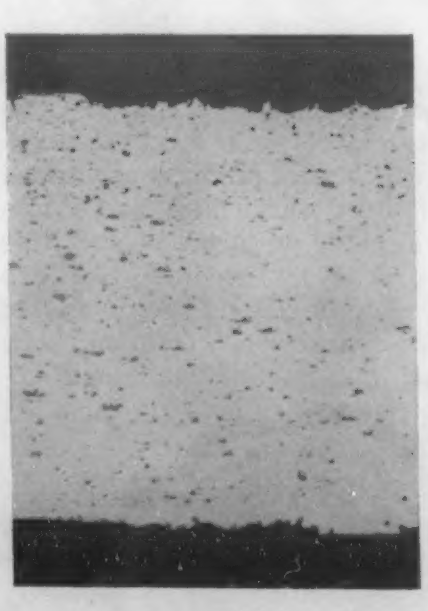
Tests are in progress to determine in detail the strength of various typical joints with various types of rivets.

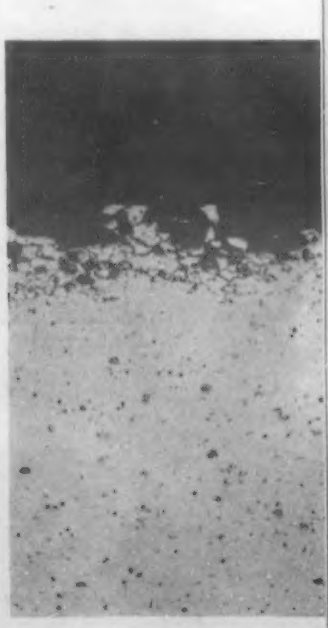
Painting and Anodizing. R301 can be anodized and colored using the same practices as for other aluminum alloys, and the behavior in corrosive media of anodized R301 does not differ from that of other aluminum alloys.

R301 can be painted like any other aluminum alloy. The article to be painted may be either anodized before painting, or carefully cleaned to insure proper contact of the paint and the metal.

Fig. 27. R301 corroded 24 hr. in $NaCl$-H_2O_2 solution. Pitting corrosion only. 75X, not etched.

Fig. 28. R301, 0.025 gage soaked 40 min. at 940 F. Intergranular corrosion caused by excessive diffusion. 75X, not etched.





Protection of Steel Parts for Overseas Shipment

by **HAROLD A. KNIGHT** METALS AND ALLOYS

ENGINEERING ACHIEVEMENTS

One of the most disturbing problems confronting the U. S. Army supply services in 1942 and 1943 was the critically high loss of valuable steel equipment and parts owing to rusting and other damage during overseas shipment. The technical resources of American industry were therefore mobilized to develop economical protective materials and "packaging" methods that would insure the uncorroded transport of virtually all war equipment shipped and without introducing production, shipping or combat-use delays. Army and Navy personnel, too, participated heavily in this ultimately successful program, out of which have come a series of rustproofing and packing methods that not only completely solved the military-supply problem involved but will be the foundation of all post-war packaging of steel parts as well. In pointing up this wartime engineering achievement, Mr. Knight outlines the basic problem and describes the various methods that were developed for its solution. *—The Editors*

"PACK IT RIGHT to reach the fight!" enjoins Charles M. Parker, Secretary Technical Committee, American Iron and Steel Institute. "Cases are known in which steel products are loaded and unloaded from railroad cars, ships and trucks 22 times before reaching final destination—and little of the handling was done by experts. The two principal hazards in shipping steel products are mechanical damage and corrosion," continues Mr. Parker. "At one time the fate of Stalingrad depended on American cold rolled strip getting through safely. It is when steel has been worked cold that rust gets in its most deadly work."

If so much pains must be taken with plain steel, still in the form of a raw material, how much more care is necessary with highly machined parts, fitted to tolerances measured in thousandths of an inch—such as gun range finder equipment and radar!

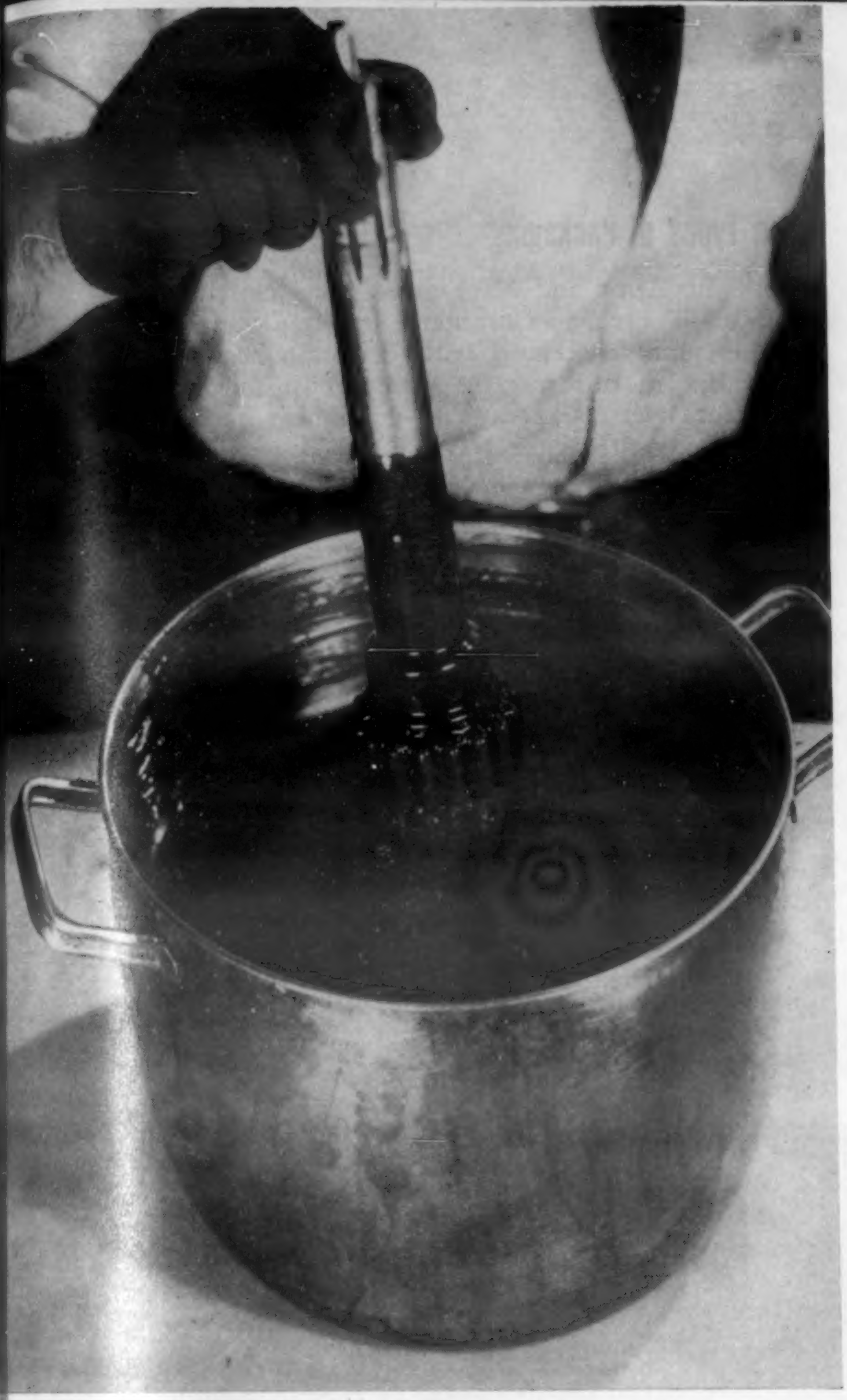
A jeep requires one third of its weight in packaging material; in the case of a cargo trailer, more than one half of its weight is packaging. In fact about half of our packaging materials production just now are carrying supplies to our armed forces.

Packaging was a bottleneck in most steel mills that do a large overseas business in mid-June, according to a report to the War Production Board by the Sheet and Strip Industry Advisory Committee. One member said that his shipments had been considerably delayed due to lack of personnel and materials needed for wrapping and bundling. Half the space in his finishing department was then being used for packaging purposes.

The nation has become packing and packaging conscious as never before. And it is high time! In prewar days American exporters often suffered in competition with other nations, principally Germany, because goods arrived at destination in lamentable shape, with boxes, crates, kegs and burlap bags torn open, some of the goods missing completely and other goods bent, distorted, corroded or broken. We are now learning much that will place us at the top in our post-war export business.

In the early days of our overseas shipments in the present war at least a fifth of our goods, safely surviving submarine attacks, arrived at destination damaged from corrosion or mechanical shock. Now manufacture of protective materials is Big Business. The use by our Ordnance Department of acid-free greaseproof wrapping papers alone equals 12,000,000 to 15,000,000 sq. yd. a month, enough to cover 37,000 acres in a year. Two years ago the paper industry produced 16,000 tons of waterproof paper yearly; today, over 200,000 tons.

Specifications of both Army and Navy insist that ordnance be packed to resist temperatures from minus 40 F. to plus 130 F., represented by the climate



A shaft is being dipped in Stripcoat, made by the Dow Chemical Co. The coating can be applied manually or mechanically, the latter providing more uniformity of coat. Ideal dipping temperature is 375 F.

extremes of Iceland and Guadalcanal. The obvious corroding enemies are salt water and spray, fog, rain and sun. There are several rarer hazards. Thus coral sand has a terrific abrasive action. Swamps in jungles may exude much sulphur.

A Russian metallurgist, arriving in the United States, revealed how oiled steel plates were carried by Russian women for long distances from shipside. German planes strafed these carriers, bullets knocking scale off the plates into the women's eyes. Scale did more damage than bullets. Heavy grease was thereafter applied to the plates, serving to hold the scale.

So skillful has our packaging by now become that many anecdotes reveal near-miracles. Brig.-Gen. E. E. MacMorland, chief, Field Service Maintenance Branch, Ordnance Dept., relates:

> I was watching guns and accessories being unloaded. One piece was a mechanism used to direct anti-aircraft fire, weighing a quarter of a ton, but so precise and delicate it is made in air-conditioned rooms where the slightest flake of dust is kept from its watch-like interior. The heavy metal parts are balanced nicely to move on precision gears, calculating height, speed and direction of enemy planes—then directing gun fire.
>
> As I watched I saw this precision instrument crash. We opened the crate and found the mechanism undamaged. The director had been padded in paper—no ordinary paper, but a cushioning device that the Ordnance-Industry team developed. After trying steel spiral springs and wood cantilever springs, we hit on special built-up corrugated pads, wrapped and sealed in heavy water-proof paper. These pads are cheap, easy to assemble and protect perfectly. Sometimes these delicate machines have to be thrown off into the surf, or onto sands of lonely islands, exposed to salt air, piled on icy shores, or buried beneath desert sands.

Packaging has developed to such an extent that G.I. Joe himself is packaged where there is danger of Hitler or Hirohito throwing gas. Every soldier in fighting zones carries a small compact package designed for split second use as a complete cover to protect him against irritant gases, allowing him an opening for thrusting out his rifle. Most of the bag is opaque and G.I. color, but the top quarter is transparent for sight.

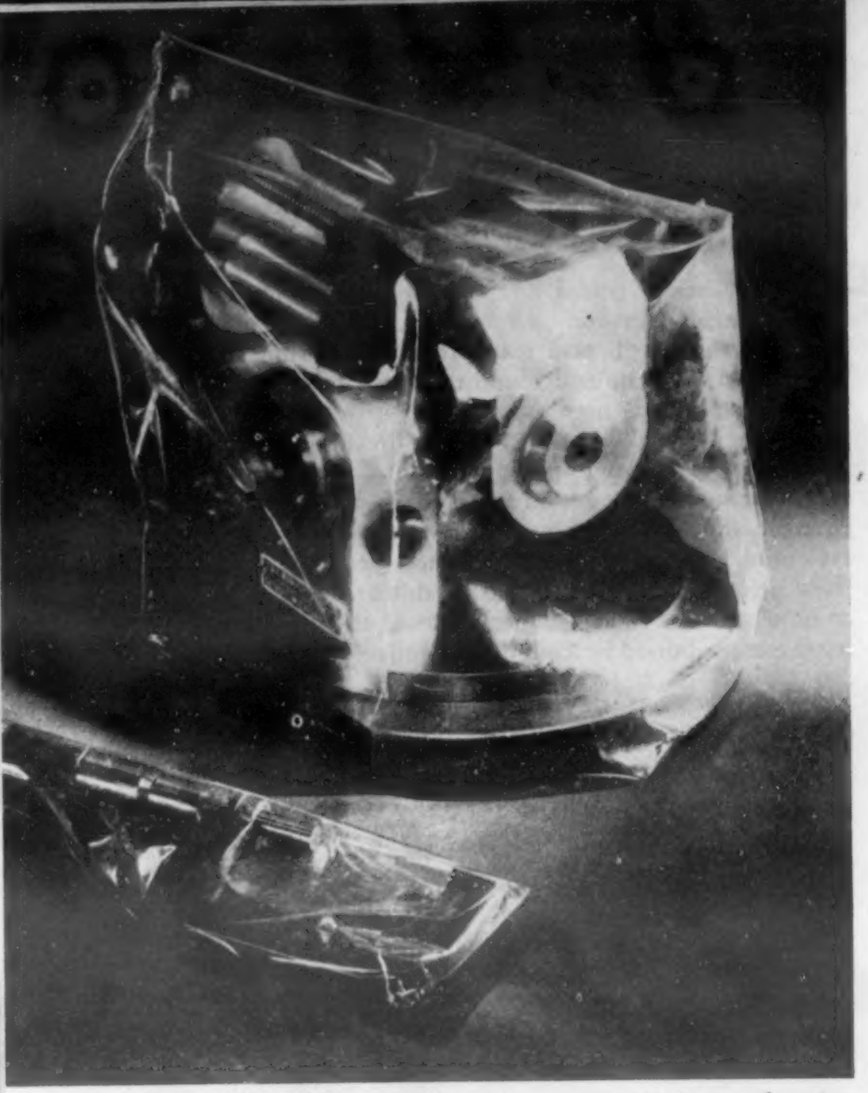
Modern and Spectacular Methods

At the risk of making the rest of this article an anti-climax, we will mention first the latest and most spectacular packaging. Airplanes shipped on the decks of ocean-going freighters are now "crated" with a spray of scientifically formulated plastic compound, based on Vinylite resins. Shot from a spray gun, it hardens in less than 30 min. into a protective coating that hermetically seals the entire plane, guarding it from heat, cold, sleet or salt water. At debarkation points the plastic coating is readily stripped by three or four men in an hour. Peelings can be salvaged, remelted and re-used.

Previously planes were partially disassembled, with fuselage in one case and wings, tail surfaces, etc. in smaller cases, all stowed below decks. When planes were first carried on decks, completely assembled, various petroleum compounds were used—fairly effective for waterproofing, but none of sufficient moisture-vapor barrier characteristics. Moreover the petroleum coatings would harden and often develop shrinkage cracks. It took 250 man-hours of labor and large quantities of solvents to remove them.

The new coatings based on Vinylite resins form an elastic film that flexes with the movement of the plane, does not harden or become brittle by exposure to sun, wind, or cold and is readily removed by merely slitting and stripping. It will not pull or lift paint when stripped. Very important is the low moisture-vapor transmission rate, the desideratum of all packaging of sensitive materials.

By tests, a film 0.003 in. thick, formed by two sprayed coats, transmitted only 0.47 grams of moisture per 100 sq. in. per 24 hr. A film, 0.0045 in. thick, three coats, transmitted only 0.29 grams. A modified compound does 0.18 grams for 0.006 in. thickness. (The Army and Navy declare that materials are moisture-vapor-proof if they have a maximum m-v transmission rate of 0.25 gram of water per 100 sq. in. at a m-v pressure differential of 42 mm. of mercury at 100 F.)



Saran film is a one-ply transparent moisture barrier, developed by Dow, ideal for precision parts and instruments and ready for use on arrival.

Because this coating fills and seals all of the smaller seams much taping formerly needed can be eliminated. Small openings are covered with heavy tape and larger ones with plywood fillets. Then the entire plane is sprayed with three coats of the resin base coating. An airplane can be completely processed by two men in less than one hour. Applied in a continuous film, it produces a tailor-made pattern that completely protects its cargo.

Suppliers of these new spray coatings are: Aviation Packaging Corp., Better Finishes and Coatings, Inc., Dade Brothers, Inc., Irvington Varnish & Insulator Co. and Plastiphane Co. of America.

Another extremely modern packaging material is "Stripcoat," made by Dow Chemical Co., that eliminates the following four packaging operations heretofore necessary: Application of preservative, cutting grease-proof wrappers to the proper size wrap, wrapping the part, and dipping the package in wax. All metal parts having continuous outer surfaces can be packed with Stripcoat; also numerous parts with internal surfaces. Thus a spark plug can be so coated, if the vertical dip is used, as the coating will bridge the opening, thus preventing the melt from traveling to the inner surfaces where it would be hard to remove.

Stripcoat is a hot melt dip that can be applied by hand or mechanical dipping. Assembly crews in combat areas can strip the coating quickly and easily without degreasing. Users of Stripcoat claim a 60 to 95% saving in packaging time.

Having considered some of the more glamorous features of packaging it is well to consider the more humdrum principles and rules of packaging, at the same time classifying the methods, with comments by experts on good and bad features.

Three Types of Packaging

Both the Army and Navy agree quite closely on classification and specification. By tradition the Navy is more concerned with corrosion than the Army. But in this war the Army must move all equipment overseas, hence its equipment receives the same exposure as the Navy's.

Three main divisions of packaging are:

I. Unsealed wrappings,
II. Sealed wrappings (where the wrapped package is dipped in melted wax, or equivalent) and
III. Wrappings containing a dessicant, dehydrant or absorbent, usually silica gel.

The preservation of equipment usually consists of one or more of the following steps:

1. Cleaning; removal of grease, oil, fingerprint residues and other contaminants.
2. Applying preservative compounds.
3. Wrapping in a grease-proof or moisture-proof barrier, or a combination barrier.
4. Sealing against penetration by water or water vapor.
5. Cushioning, blocking or bracing.
6. Cartoning.
7. Boxing or crating.

Steps 1 to 4, inclusive, are for protection against corrosion; 5 to 7, against physical damage. It is important that various materials used be compatible with one another and with the wrapped article, lest chemical action set up and corrode the piece. We can imagine sulphur being released from the paper, say as hydrogen sulphide, to do its dirty work. Let it be said here that common sense is the best ingredient to apply. Most of this "sense," backed up by shop experience, has already been inherited or acquired. Thus by common sense one knows that a cleaned surface should be sealed promptly before contamination sets in. Sweat from fingers contains deadly corrosive acids, salt, etc. Soldering and brazing fluxes often wreak havoc.

Materials most commonly used for removal of contamination are alkaline cleaners, petroleum solvents, solvent vapor cleaners, methanol, special compounds for neutralization of fingerprints and rust removing compounds. Alkaline cleaners are more difficult to operate satisfactorily than some other types.

Petroleum solvents are frequently used prior to application of rust preventive compounds. Vapor degreasing, using trichlorethylene, perchlorethylene, or other chlorinated hydrocarbon solvents, is one of the most popular prior to rust preventative applications. Only alkaline cleaners will adequately remove fingerprints. Hence cleaning with other materials must be followed by a treatment to neutralize or remove finger contaminations.

Details of the Methods

Previously, we noted three packaging methods; these will now be discussed in more detail. Method I is for non-precision parts, rustproofed and wrapped in a "breathing pack" (not air tight). Preservative is applied to the item and the part wrapped in grease proof paper that will permit free transfer of

air and moisture to and from the part. Typical products so wrapped are semi-finished castings, non-precision solid shafts or rods, springs and metal stampings.

Method II is for parts with precision and highly finished surfaces. Material is rustproofed and the package sealed. Preservative is applied direct to the part, wrapped and the wrapping sealed, say by a dip in hot wax. Typical parts so packed are: Pistons and rings, taps and dies, gears and precision hand tools.

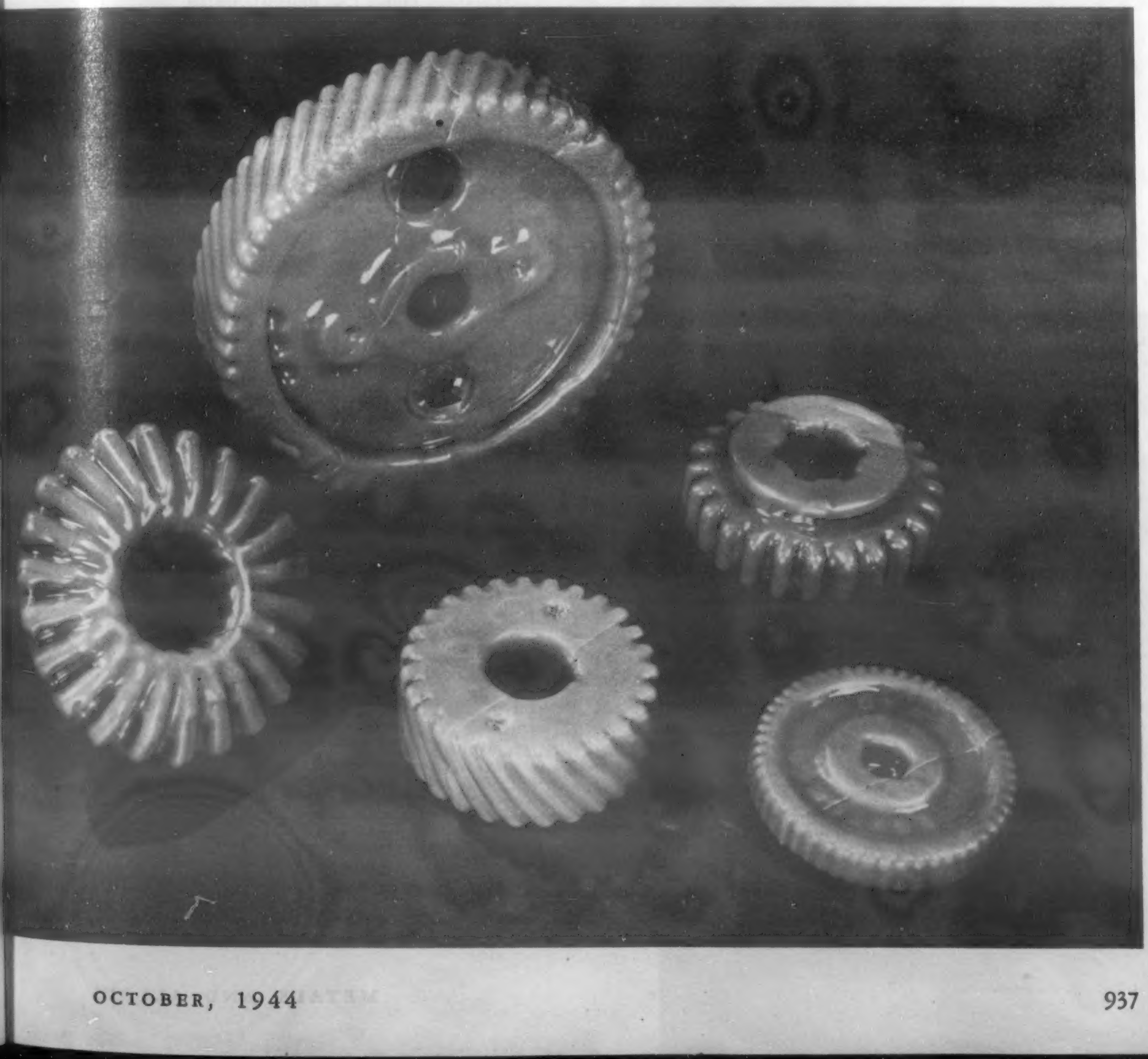
Method III provides for the part being sealed with a dehydrating agent in a moisture-vapor-proof wrapper. The cleaned part is not treated directly with a preservative. The dehydrating agent absorbs moisture inside the wrapper and the wrapper protects the part from high humidity, rain and ocean spray. This method is particularly good for assemblies of mixed metallic and non-metallic materials, or where the usual rust preventive on the metal parts would injure by contact the non-metallic parts, such as rubber. This method is suitable for fire control instruments, coils, condensers, generators, gages, etc.

For Methods I and II grease type preservatives are in general the best of the compounds for storage and export shipment. They are normally applied by dipping at 160 to 200 F. Or, they may be applied by spraying or brushing. Chief disadvantages are that they are messy to handle and the preservative must be removed before a part is put in service. In general, soft greases will be best for small parts and hard greases for large parts.

The accompanying Table shows the leading types of preservatives now in use, their characteristics, and the companies who manufacture or distribute them.

Method III is based on the knowledge and experience that most metals will not corrode if the relative humidity is below 20%. Silica gel maintains that deadline. It also conforms to the requirement of being able to absorb large quantities of moisture (at least 8.5% of its weight to keep humidity below 20%). The chief drawback is that preservation is good for a finite period only. When the dessicant is exhausted, the package must be opened and the dehydrating agent replaced. The Navy specifies that enough dehydrating agent be packaged for protection over 18 months.

Gears are often double-dipped in Stripcoat, with a good over-lap joint to insure against entrance of moisture.



Preservative Materials Now in Use and Their Manufacturers

American Iron & Steel Inst. Type No.	Army, Navy & Fed. Specs.	Characteristics	Manufacturers
AEX	2-82C AN-C-52 (type 2, grade B) AXS1001	Hard, thick-film, heavy compound, protracted (several yrs.) corrosion prevention of highly-finished parts; applied by heating to right consistency (no solvents) then dipping, spraying or brushing	Alox Corp., Niagara Falls, N. Y. American Lanolin Corp., Lawrence, Mass. American Lubricants, Inc., Buffalo, N. Y. American Oil & Supply Co., Newark, N. J. Anderson (F.E.) Oil Co., Portland, Conn. Ball Chemical Co., Pittsburgh, Pa. Black Bear Co., New York, N. Y. Bray (O.B.) Co., Los Angeles, Cal.
BEX	2-84b AN-C-52 (type 2, grade A)	Soft, thick-film, light compound; good for 1 year or less on highly-finished items; applied like AEX	Carbozite Corp., Pittsburgh, Pa. Cities Service Oil Co., New York, N. Y. Dearborn Chemical Co., Chicago, Ill. Delta Oil Products Co., Milwaukee, Wis. Du-Lite Chemical Corp., Middletown, Conn.
CEX	AXS-673 AN-C-52, type 1 52-C-18, grade I	Solvent-containing, thin-film compound; for parts that have neither highly finished nor critical surfaces. Develops abrasion resistance on aging. Applied without heating or dilution	Freedom Oil Co., Freedom, Pa. Frost Paint & Oil Co., Minneapolis, Minn. Glidden Co., Cleveland, O. Glyco Products Co., Inc., Brooklyn, N. Y. Gulf Oil Co., Pittsburgh, Pa.
DEX	52-C-18, grade III	Non-drying water-soluble oil. May be a polar-type (water-displacing) material	Hollingshead (R.M.) Corp., Camden, N. J. Houghton (E.F.) Co., Philadelphia, Pa. Humble Oil & Refining Co., Houston, Tex. Johnson (S.C.) & Son, Inc., Racine, Wis.
EEX	AXS-702 O.S. 1362	Light, non-hardening, very-thin-film lubricating oil; excellent temporary protection. Applied without dilution	Kendall Refining Co., Bradford, Pa. Lehigh Chemical Products Co., Allentown, Pa. McCambridge & McCambridge Co., Baltimore, Md.
FEX		30-50% non-volatile varnish	Nox Rust Corp., Chicago, Ill. Pennzoil Oil Co., Penn, Pa. Penola, Inc., Pittsburgh, Pa. Presstite Engineering Co., St. Louis, Mo.
GEX		Primary coating (8-12% non-volatile soluble varnish-base residual on steel) applied in the form of a hot water solution	Quaker Chemical Co., Conshohocken, Pa. Quaker State Refining Corp., Oil City, Pa. Rosco Laboratories, Inc., Blawknox, Pa.
HEX	AXS-674 O.S. 1363	Non-hardening, thin-film, medium lubricating oil. Used on internal highly-finished surfaces. Applied without heating or dilution	Scholler Bros., Philadelphia, Pa. Shell Oil Co., New York, N. Y. Simoniz Co., Chicago, Ill. Socony Vacuum Oil Co., New York, N. Y. Sonneborn (L.) Sons, Inc., New York, N. Y. Standard Oil Co. of Indiana, Chicago, Ill. Standard Oil Co. of New Jersey, New York, N. Y.
JEX		Bituminous-base, quick drying, hard film	Standard Oil Co. of Ohio, Cleveland, O. Sta-Vis Oil Co., St. Paul, Minn. Texas Co., New York, N. Y. Thompson Paint Co., Pittsburgh, Pa. Turco Products, Inc., Los Angeles, Cal. Union Oil Co., of Calif., Los Angeles, Cal. Viscosity Oil Co., Chicago, Ill. Zophar Mills, Inc., Brooklyn, N. Y.

The Army prescribes the following formula: W equals 0.2A plus ½ D, where W equals weight of silica gel in pounds; A equals area of enclosing wrapper in square feet; D equals weight of enclosed hygroscopic dunnage, such as cartons, etc.

Manufacturers of silica gel for dehydrated packaging include Davison Chemical Corp., Baltimore; Permutit Co., New York; American Cyanamid & Chemical Corp., New York; Morgan, Inc., Chicago and International Filter Co., Chicago.

One of the most important developments of this war in packaging has been the Grade C wrapper, impervious to oils and greases, and with a high resistance to water and moisture vapor transmission. The original C wrapper was used to protect underground pipe lines against corrosion and was adapted for export shipment. It consisted of a sheet of cellulose acetate laminated to a sheet of muslin with a micro-crystalline wax base compound. This has since been supplemented by other materials, including cellophane or cellulose acetate laminated to paper with microcrystalline wax and various metal foils laminated to paper with asphalt base compounds.

Some Newer Techniques

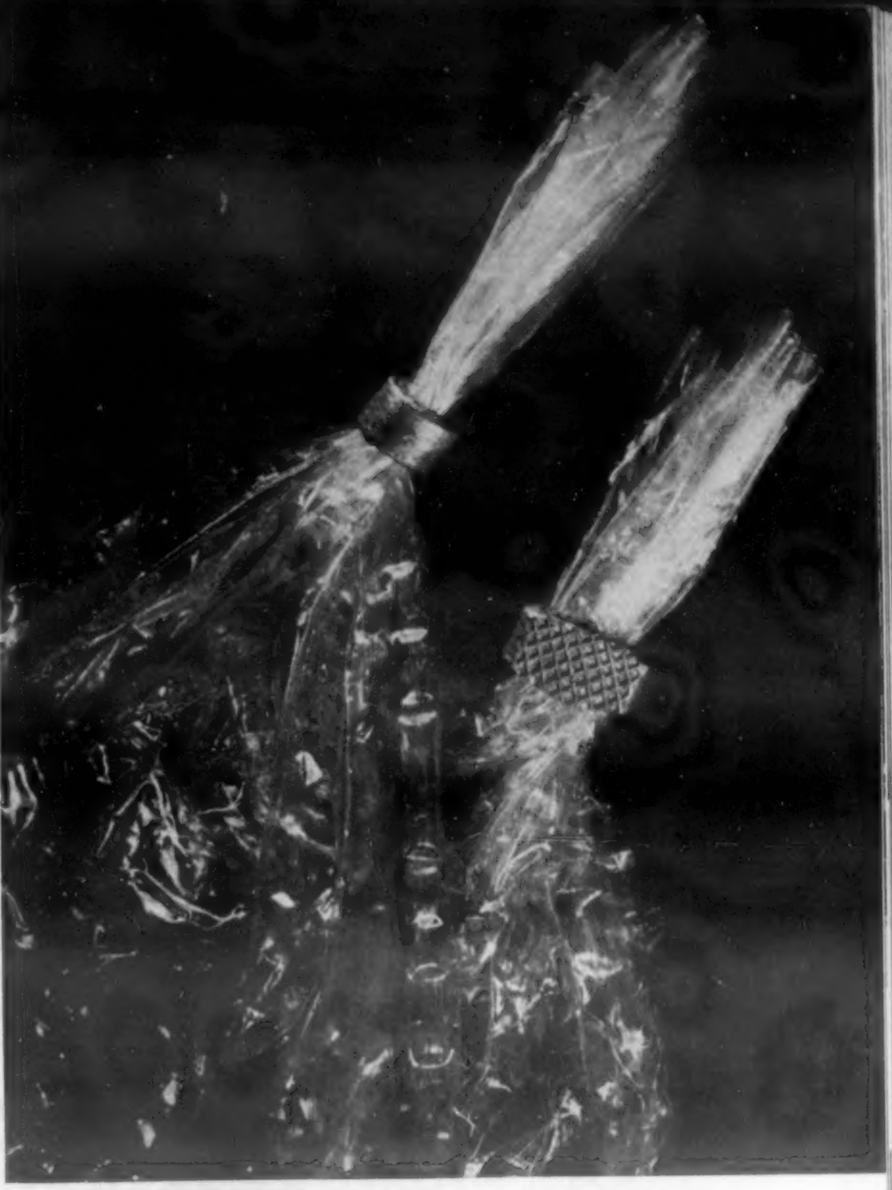
Among other materials recently developed for moisture vapor barriers are plastic films such as Pliofilm and Saran and certain Kraft paper asphalt laminations. A variation is the introduction of a lead sealing ring. Thus a machine gun, after preliminary treatment, is inserted along with a dessicant carton, into a knitted bag and then placed in a tubular section of transparent plastic material, such as Saran (made by the Dow Chemical Co.). The ends of the tube are gathered and slipped through the small lead ring (made by E. J. Brooks, Newark, N. J.), which is crimped tightly by a small hand press, thus sealing the envelope. A second knitted bag and specially designed wooden box complete the package.

Should it be necessary to reopen the package, a screw driver or punch is sufficient. Thereupon the ring is replaced on the plastic and recrimped with a blow from a hammer.

The "skin" coatings, such as Stripcoat, mentioned earlier, have several important advantages, chief being a saving in manpower and floor space. Much less handling and equipment are required. One of its disadvantages is the loss of a large amount of protection when the coating is damaged. The skins are usually applied by dipping the part in the plastic at 325 to 375 F.

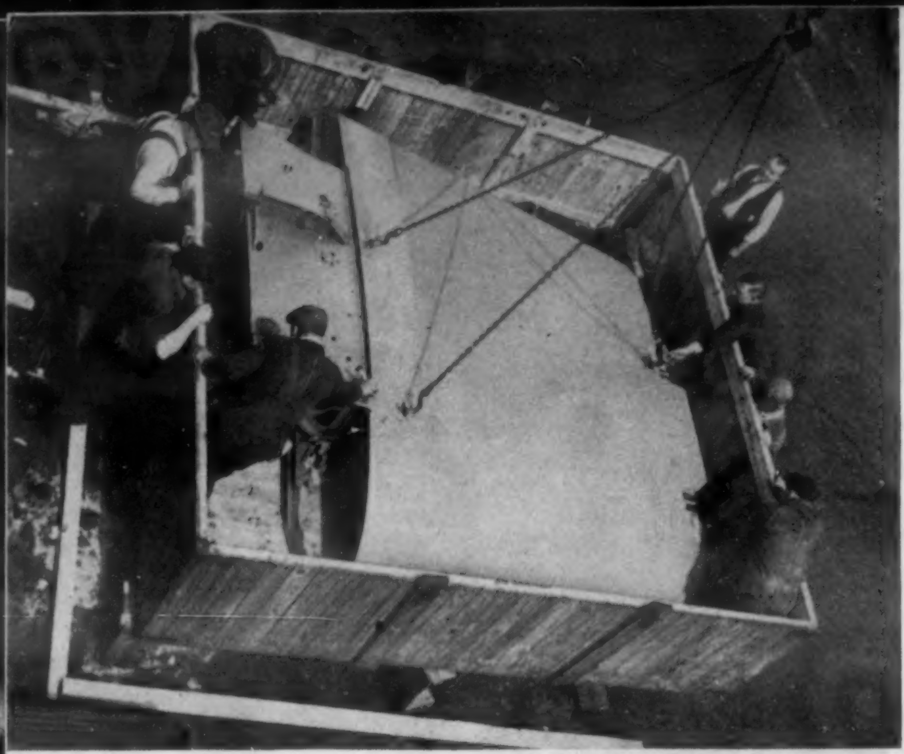
In view of the importance of packaging, manufacturers are turning out considerable patented or proprietary equipment. Thus for hot wax dipping the Aeroil Burner Co., West New York, N. J., has developed two new electrically-heated, portable hot wax dip tanks that prepare for both dipping and spraying. They are equipped with dip baskets, heavy duty grills, built-in thermometers and thermostats, giving automatic heat control from 100 to 550 F.

Another of the skin type wrappers is that recently announced by the Japan Co., 5103 Lakeside Ave.,



A lead seal ring is often used to close the opening of a film bag in which may be a machine gun, instrument or metal part. The malleable lead ring can be squeezed tight by pressing with hand pliers.

The ethylcellulose coating, made by the Japan Co., Cleveland, has been stripped off this part, which is now theoretically ready for use.



That old stand-by, wood, finds ready use for protection against shock and mechanical damage. Here an airplane part is being hoisted into its crate and will be held in place with papers, dunnage, etc.

Cleveland, who advertise that the parts are coated with an ethylcellulose plastic material which encases them with a tough, cohesive film, making air or moisture penetration impossible.

An interesting "War Packing Manual" has been issued by the Sherman Paper Products Corp., Newton Upper Falls, Mass., containing samples of a "baker's dozen" of papers, called "Corroflex." They are claimed to be greaseproof, acid-free, non-corrosive, moldable and sealable. Many of them are corrugated. Also impressive is the "Induwrap" of the Angier Corp., Framingham, Mass., called a "dual" wrapper. It is a corrosion inhibitor and an oil barrier that keeps slushing oil from penetrating through to the outside of the package.

The following three companies are prominent in the manufacture of "ordnance wrap" papers: McLaurin-Jones Co., Brookfield, Mass.; Rhinelander Paper Co., Rhinelander, Wis. and Nashua Gummed and Coated Paper Co., Nashua, N. H.

A company that makes emulsions, solutions, hot melts, heat sealing compounds, etc. is the American Resinous Chemicals Corp., Peabody, Mass.

Protection Against Shock

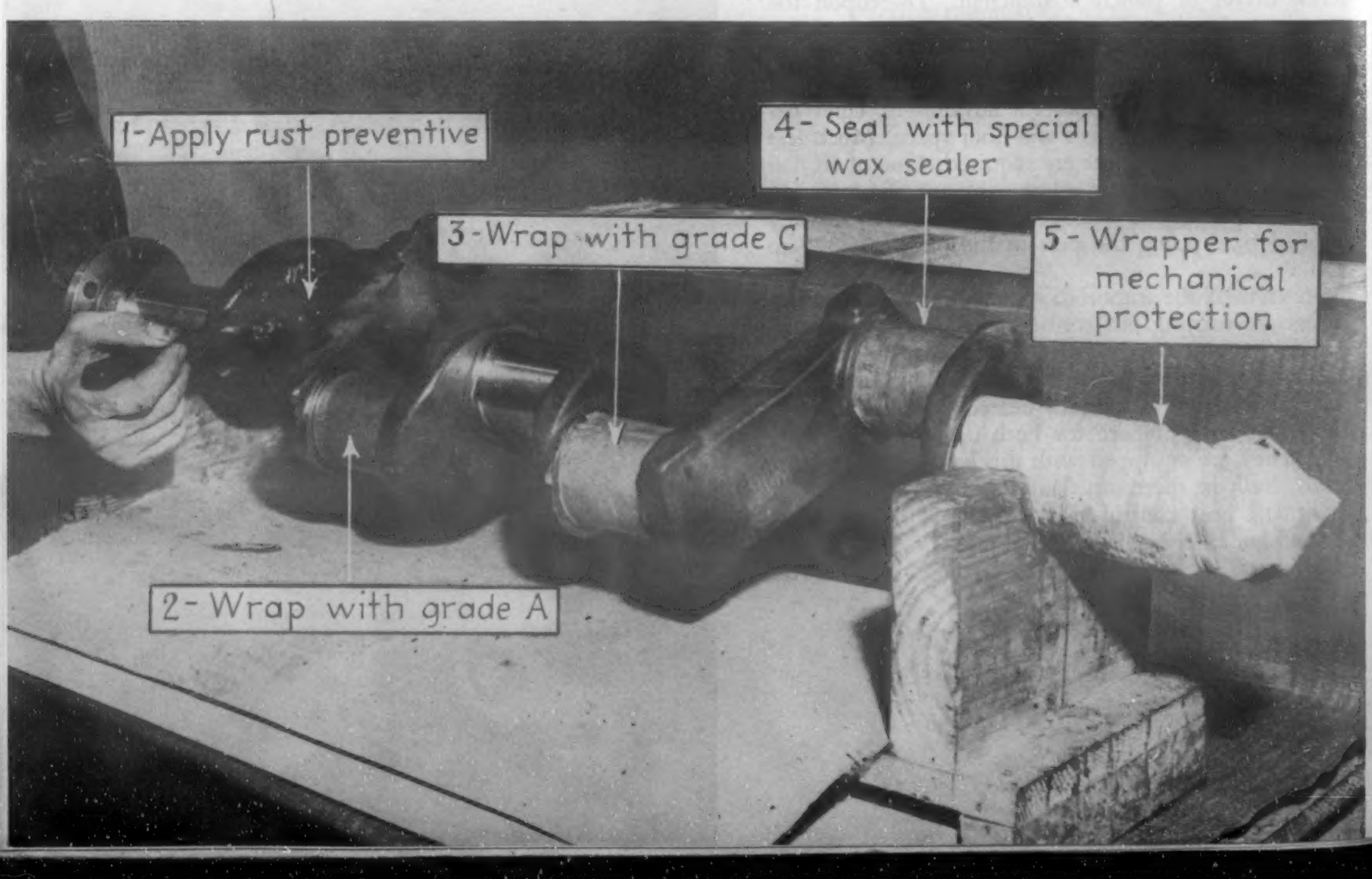
Most of this article has been devoted to guarding against corrosion, naturally the most complex phase of packing. Guarding against mechanical shock is of course important, but data are already fairly well known. It is usually recognized that the best available material for exterior packing cases is wood. By using proper design, wood packing cases, wire-bound boxes and crates will have the necessary strength, resistance to puncture and cushioning against shock.

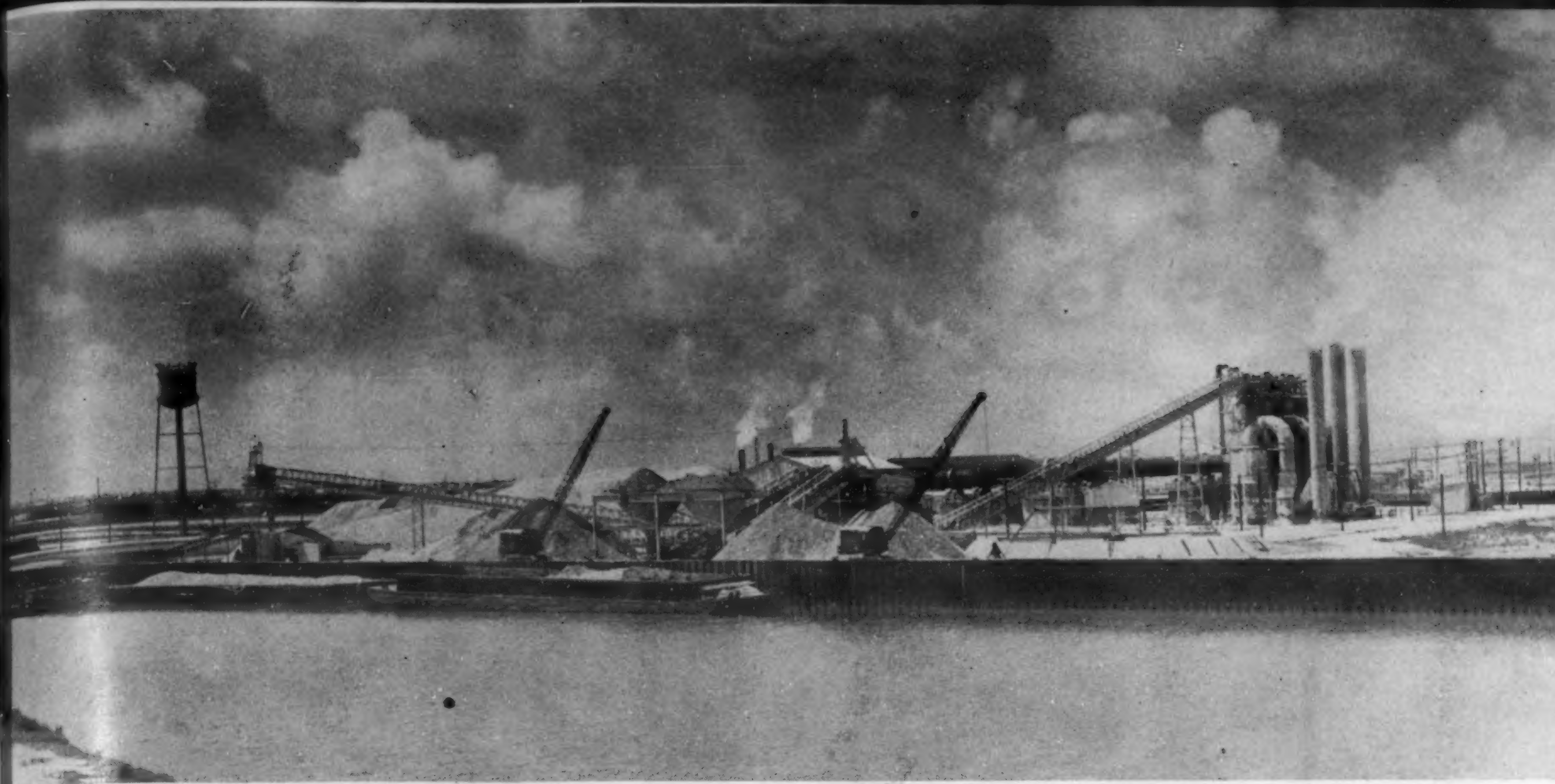
Spectacular is a recent boxing job announced by the American Iron and Steel Institute. A single wooden box, filled with blood plasma or food, and tied together with a special kind of steel wire, can be dropped 10,000 ft. or more from an airplane without a parachute. When opened every bottle will be found intact. A strong alloy steel wire has been used, applied by a simple, hand-operated machine and bound together in a strong, twisted tie.

When the box hits the ground it bounces end-over-end about 30 ft. back into the air. It is the wire binding that acts as a shock absorber. It gives a little and absorbs most of the bursting effect generated by the terrific impact of the fall. If the wire were too weak it would snap and the box and its contents would seem to explode. Too strong a wire would bind the box too rigidly and it would collapse under the blow. Eggs will not break, but electric lamp filaments will.

For many facts above narrated, we are indebted among others to C. E. Heussner and C. O. Durbin, Engineering Div., Chrysler Corp., recognized authorities on this subject.

Application of corrosion preventive and protective wrappers for a crankshaft, as recommended in Army Service Forces Manual M406. Grade A and C wrappings are defined in Ordnance Dept. Spec. AXS-840.





At the other end of the barge canal oyster shells are unloaded either to storage or directly to the kiln feed hoppers at the right. The turning basin is in the foreground.

Magnesium from Sea Water

by GERALD E. STEDMAN

ENGINEERING ACHIEVEMENTS

Among the achievements most frequently mentioned in informal recapitulations of recent engineering and metallurgical advances is the process for extracting magnesium metal from the sea developed by the Dow Chemical Co. over a period of many years and applied with telling effect on our enemies in this war. Here is presented the panoramic background of this peculiarly American development, with a discussion of the engineering, metallurgical and chemical aspects of the process and a description of the Dow-operated Velasco, Texas plant for carrying it out. *—The Editors*

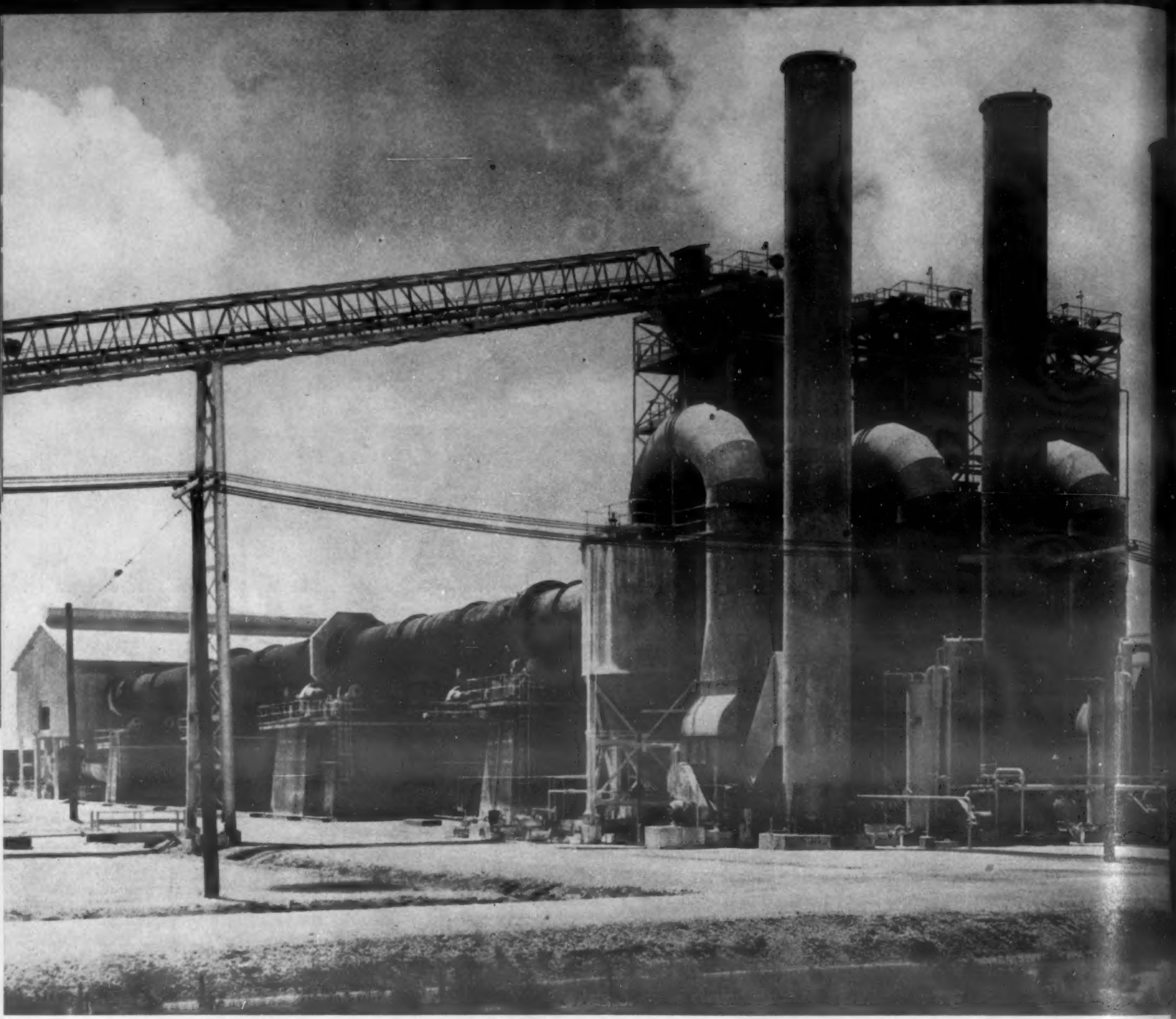
PAUSE IN YOUR STUDY of Invasion maps. Swing the globe around to the Texas Gulf Coast. Place your pencil midway between Galveston and Matagorda Bay. Define a seven mile triangled area inward, with the harbor of Freeport as its apex. There you will find constructive cartography being accomplished.

In this Freeport-Velasco area, the independent resourcefulness and determination of Dr. Herbert H. Dow and later of his son, Dr. Willard H. Dow, has flowered into a development of almost miraculous nature, from the public's point of view. The area encloses four Dow enterprises.

(1) The Dow Chemical Co. plant which began producing magnesium in January, 1941.

(2) The Dow Magnesium Corp. which operates the Velasco Defense Plant Corp's 72,000,000-lb. magnesium plant, production having started in June, 1942. (A Defense Plant Corporation enterprise of like capacity is operated by the Dow Magnesium Corp. at Ludington and Marysville, Mich.)

(3) The Styrene Division of Dow Chemical Co., largest of its kind in existence, operated for D.P.C. along with its Los Angeles D.P.C. styrene undertak-



The lime plant is well designed and one of the most efficient units in the country. Here oyster shells are calcined and slaked to produce milk of lime. Flow in the kilns is from right to left in this view.

ing, which, with its Midland, Mich. and Sarnia, Ontario facilities, is manufacturing 50% of America's styrene for GRS (Buna S) Rubber.

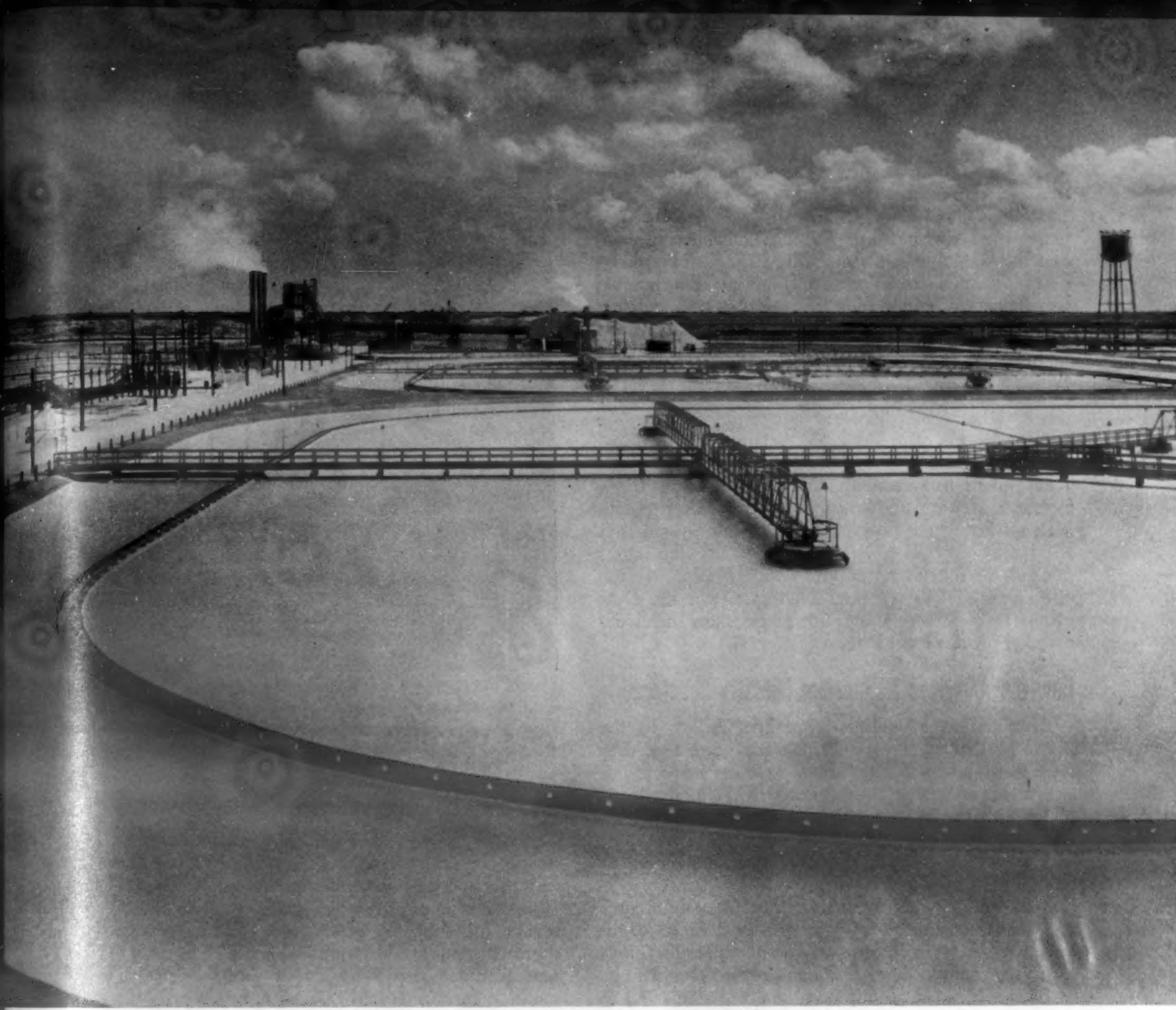
(4) Texas Division of the Ethyl-Dow Chemical Co., largest ethylene dibromide plant in the world. The concern of this article is solely with the processes of Dow Magnesium Corp. at the Velasco plant.

Magnesium from sea water, over 72,000,000 lb. per year—at this one spot alone; a tongue of formerly desolate waste land bordered on three sides by Freeport Harbor's ocean water, four years ago a flat nothingness of salt grass 7 ft. above sea level and inhabited largely by moccasins, coral snakes and whopping rattlers. Now it is an empire of chemical production, doing its mighty part in changing the term "invasion" to liberation. Just 10 miles away from it, centered in the semi-tropical verdure of Lake Jackson, Alden Dow is applying his individualized architecture to the development of a delightful community in the woods, as an essential part of the enterprise. Thanks to this leadership, we have a potent magnesium industry.

Some Historical Facts

The Freeport-Velasco enterprise culminates from the steady purpose of 57 yr. of growing endeavor that began in 1887, as Herbert H. Dow, senior at Case School of Applied Science, Cleveland, explored for his degree by passing electric currents through brine filled test tubes. His endeavors grew in significance from Canton to Midland, and in 1905 he first whipped the Germans in their acknowledged realm of chemical leadership, by undercutting them in the Continental market on bromine, forcing them to retreat from the U. S. market.

The same thing happened with bleach, and the Teutons again withdrew. And yet again, when World War I made us seriously vulnerable because of dependence upon German chemicals, the Midland group found quick and effective ways to produce phenol, chlorobenzine for making picric acid, together with aspirin, Epsom salts, indigo; later becoming one of the world's largest dye producers.



The sea water, after mixing with milk of lime flows to these Dorr ponds where the magnesium hydroxide settles out. Each pond contains four 200-ft. diam. Dorr mechanisms.

Magnesium was used largely then (1916) for pyrotechnic purposes and as a deoxidizer in the manufacture of nickel. Winning magnesium chloride ($MgCl_2$) as a byproduct of its Midland bromide production, the Dow group began experimentation in metallic magnesium. Dr. Dow's first principle in all production has been to make it better and cheaper than anyone else.

A pound cake of magnesium was first produced by the Dow group in July, 1916, by somewhat crude electrolytic methods. A cell had been hand made from welded boiler plate, partitioned and lined with soapstone, with an iron plate in one section and a graphite rod in the other; both electrodes being connected with low-voltage, direct current. The entire cell thus contrived was boxed with soapstone slabs.

On the hot night of July 20, the group watched on, unconcernedly breathing chlorine gas, as the cell was heated over a brick arch, molten magnesium chloride was poured in and the current turned on. As they alerted to the phenomenon, the historic significance of those little globules of mercurial opalescence floating on the surface of the bath seemed of less interest than that, to their surprise, the electric current was found sufficient to keep the salt bath molten. The projection of that night's discovery can quite properly be considered an assurance of winning World War II—for without the continuing perseverance of that Dow group, we could have lost.

Discouragements were intense. On an Autumn day in 1917, the same group saw a new magnesium plant of 25 cells, capable of 300 tons per year, go into production. As current came on, some cells overheated, short circuited, and other cells froze. Chlorine gas choked the atmosphere. Cell pots cracked and spilled their molten metal across the floor. The sal ammoniac corroded. Everything seemed in a tailspin. The plant closed, a failure. World War II could have been lost again right there, but for the indomitable determination of Dr. Herbert Dow, who casually remarked that he thought the group had learned enough to make another and better cell. It had.

The sal ammoniac process of evaporating a solution of ammonium chloride and magnesium chloride, crystallizing out a double salt, air dried and fused to gain a clear, water-free magnesium chloride was abandoned. A double salt was evolved by partially dehydrating magnesium chloride and mixing it with equal weight of sodium chloride, the mixture being melted at controlled temperature. The addition of common salt to magnesium chloride lowered its melting point and a little fluorspar helped coalescence. They discovered that the liquid of the fused cell bath made the best flux, this discovery being the basis of the present process of melting and reclamation.

They did a lot of things, but in February, 1920, after a new plant had been operating successfully for six weeks, a melting pot broke and the gushing molten bath set fire to the building. Out of the twisted iron and steel, only salvage was a pile of magnesium ingots stacked on the floor, unharmed by the fire that no one knew how to put out. All this taught the Dow group that extraction of pure magnesium metal demanded precise technique.

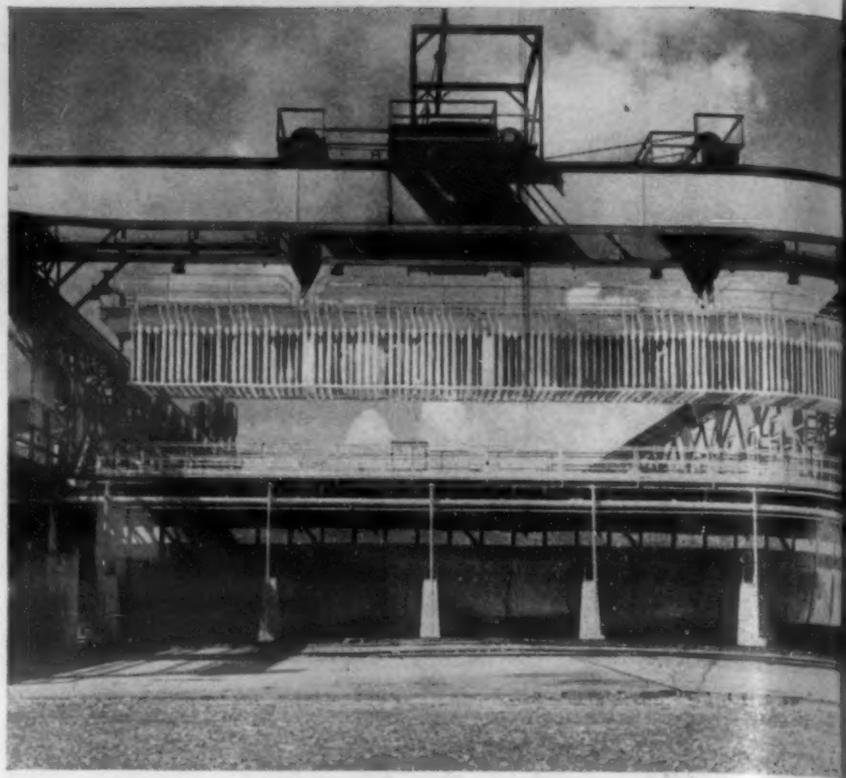
How the American Magnesium Industry Developed

Examination of German bombers falling in the Battle of Britain showed British engineers that they were using magnesium as a major rather than a minor structural metal. Messerschmitts had hundreds of pounds of magnesium housings, mountings, castings, forgings, extrusions—even magnesium weldments. That was why they were missioning such an overage of bombs to target, far above the calculated cargo relative to weight and size of plane. Magnesium gave the Germans great advantage, also, in their tremendous use of it in incendiary bombs. Magnesium's sudden war importance was apparent in the increase of Dow sales to England, from 89,600 lb. in 1940 to 3,505,272 lb. in 1941—the hundredfold increase of 9,189,558 lb. in 1943.

In effect, Dow was presented with a production monopoly by default in 1927, the ALCOA subsidiary, American Magnesium Corp., only other U.S. producer, finding that it could buy from Dow cheaper than it could produce. By 1929, Dr. Herbert Dow announced the first and final steps of separating metallic magnesium chloride from brine, and metal from the fused magnesium chloride had been sufficiently perfected as not likely to undergo change for many years. Intermediate processing steps were being perfected.

The Dow expansion program calculated a 24,000,000-lb. goal in 1938, half to be produced elsewhere than Midland. In 1933 Dow, with Ethyl Gasoline Corp. as joint owner, constructed the Ethyl-Dow Chemical Co. tidewater plant at Wilmington, N.C., to extract bromide from ocean water, producing ethylene dibromide. From this later experience, Dow learned how to handle the sea. Analysis showed ocean water to contain 20 times as much magnesium as the bromide which Dow was extracting from the sea.

So an exploration by outside engineers of the entire Gulf of Mexico, caused the selection of Freeport, Texas, as the site, largely for three reasons: (1) Raw materials of salt, sulphur, lime, natural gas, were abundant. (2) There was a most fortunate opportunity to dispose of waste liquor through a canal to the Brazos River, returning spent sea water to the ocean several miles further down from the intake where a shore current carried it southward. (3) Certain existent advantages, such as a jetty and barge canal remaining from a United States Engineers project.



The magnesium hydroxide or milk of magnesia underflow from the Dorr tanks is further dewatered in this battery of Moore filters. A filter "basket" is shown suspended over a filter pit.

Freeport magnesium production started in January, 1941. In October, 1941, as this Dow plant was nearing completion, the Defense Plants Corp. asked Dow to construct and operate a 72,000,000-lb. sea water plant at Velasco, about seven miles away. Dow likewise operates a plant of like capacity away from tidewater, the magnesium chloride extraction phase being at Ludington, Mich., and the metal extraction phase being at Marysville, both Government owned. Dow also agreed to make its know-how available to any responsible company financed by D.P.C., but only two groups took advantage of the opportunity. Eight other concerns went into magnesium production with Government money, using processes other than Dow. In November, 1943, companies owned, managed or advised by Dow had 38% of the total money advanced by D.P.C. for magnesium production purposes, and were yielding 1.2 lb. of metal per Government dollar invested. The others were yielding about 0.6 lb. In 1942, the Dow group produced 91.2% of all metallic magnesium in the United States. This saved the American air program and gave the Allies mastery of the air.

A monopoly of anything is an expensive luxury in the absence of sales. There were many times during the 1930s when inventory presented a serious prob-

lem. For example, with a 1,336,674 lb. inventory in 1931, Dow produced 1,945,998 lb. in 1932, and ended that year with an almost double inventory of 2,511,491 lb. Educationally and capably, Dow attempted promotion, exhibiting at shows, freely providing thousands of test bars, sending its technicians everywhere to counsel. Though the Packard, Wasp and Hornet engines had magnesium crank cases and Cadillac used some crankcases—and although Dow itself experimented in pistons—the markets did not respond. The Navy and Bureau of Aëronautics persistently delayed encouragement of its use. The German I. G. Farbenindustrie in wily ways tried to capture control of United States markets; being tied up with the German military machine, its aim was probably to discourage American production and catch us vulnerable at World War II's start.

Dow magnesium production grew from 20,017 lb. in 1920 to 65,430,040 lb. in 1943. Domestic price per pound declined from $1.83 in 1919 to 22¢ in 1943. It had been originally over $5.00 per lb. in 1914. The 1944 ingot price per pound is 20.5¢ freight allowed, compared to an aluminum price of 14¢. Since magnesium is one-third lighter than aluminum, the comparison on a price per pound basis is often called faulty. Perhaps it should be on a price per cubic foot comparative basis.

How the Process Operates

But now to a detailed description of the Dow Magnesium Velasco process and operation flow, the fundamental chemistry and structural reactions of the Dow process of producing metallic magnesium from seawater, as later detailed, proceeds thus:

$$MgCl_2 + Ca(OH)_2 \longrightarrow Mg(OH)_2 + CaCl_2$$

$$Mg(OH)_2 + 2HCl \longrightarrow MgCl_2 + H_2O$$

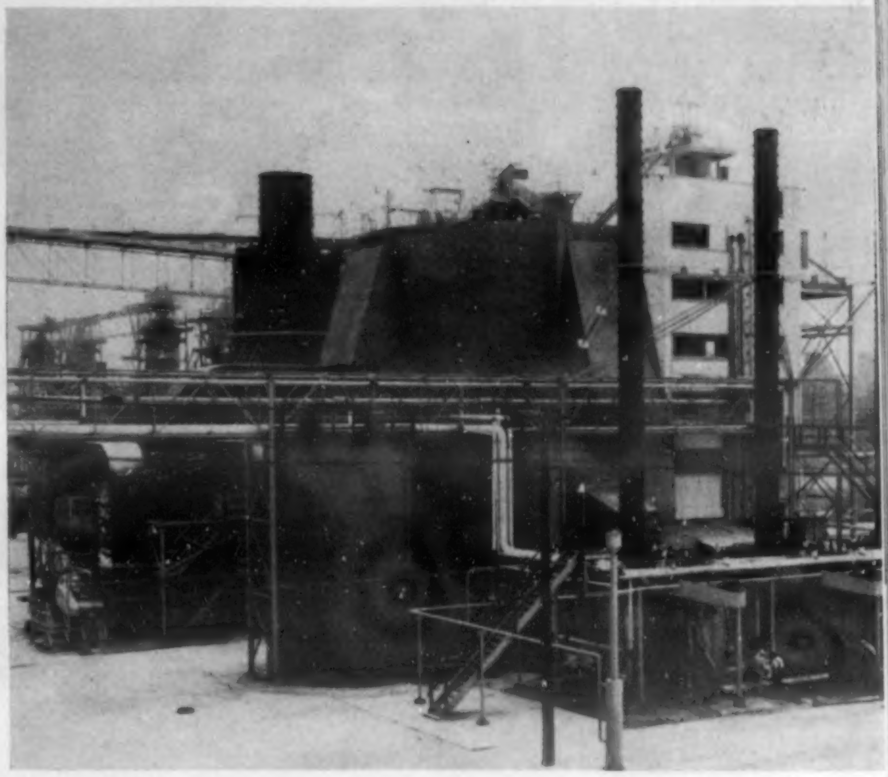
$$MgCl_2 \xrightarrow{\text{Electrolysis}} Mg + Cl_2$$

$$2HCl \longleftarrow Cl_2 + H_2 \longleftarrow$$

$$CH_4 + 2H_2O \longrightarrow CO_2 + 3H_2$$

Briefly, magnesium production by the Dow process concerns the precipitation of $Mg(OH)_2$ from sea water and lime and its reaction with HC1, subsequent evaporization and further drying to produce granular $MgCl_2$, known as "cell feed" which is submitted to electrolysis and forms magnesium metal and chlorine gas, the latter being recycled.

The process of the Freeport and Velasco magnesium plants is identical; the main difference in operation being that the Freeport plant has a short inlet of sea water and a long discharge of spent water, while the reverse is true of the Velasco plant, which draws its ocean water from a barge canal running parallel to the effluent Dow canal that conducts its waste water nearly seven miles into the Brazos River. By the way,

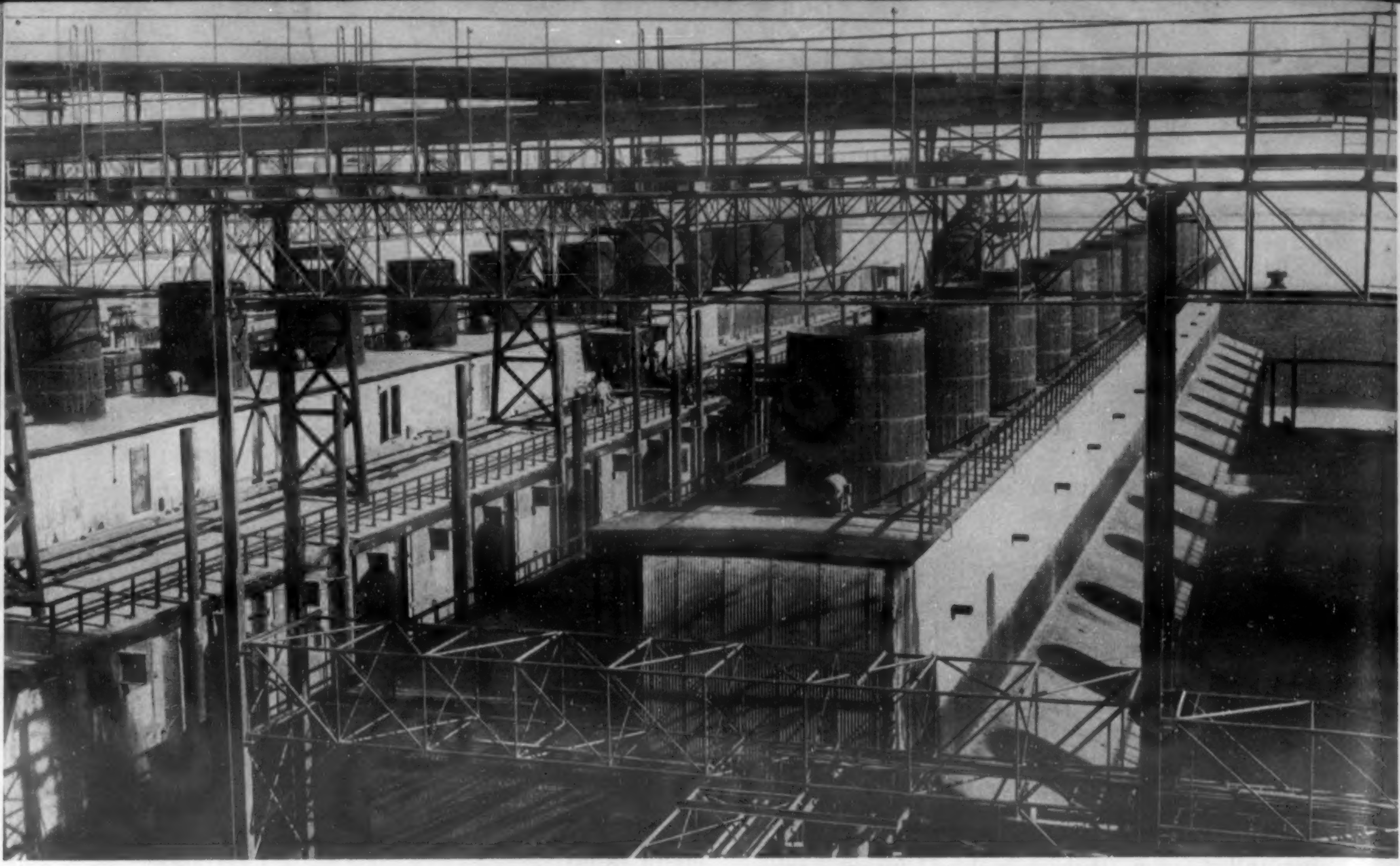


The concentrated magnesium chloride is further evaporated in the boiling kettles in the right foreground and then dried to a granular solid in the shelf drier at the center.

Dow uses its Freeport plant water to the fullest extent; not alone for magnesium extraction but as condensing water for the power house, cooling water for heat exchangers and pumps. It is then delivered to the Ethyl-Dow plant for bromine extraction.

The Dow effluent canal and the barge canal are separated by an 18-ft. levee and its channeling required removal of over 3,000,000 cu. yd. of earth. The effluent canal is 80 ft. wide and 8 ft. deep and 7 miles long. The barge canal, supplying ocean water to the Velasco enterprise is 160 ft. wide and 16 ft. deep. It accommodates ocean going barges and places Dow in water-borne cargo touch through the Intercoastal Waterway System, extending as far north as Maine, with the ramifications of the Mississippi inland waterway system and the Eastern sea coast. Oyster shells and other material are barged into Freeport-Velasco operations, while products such as caustic soda are water borne out along this extensive waterway. This barge canal originates in Freeport harbor, protected from silt and sand wash by a Gulf jetty. Paralleling the effluent canal, it runs back to terminate in a turning basin from which it is pumped into the sea water flume of the Velasco plant.

The skimmer gate is depressed 20 ft. to hold back the dilute surface water, drawing in the strong sea water from the bottom to gain its full salinity. This gate can be dropped 15 ft. to accommodate the passage of the ocean barges. The sea water has a 0.5% content of $MgCl_2$ in the turning basin and is concentrated in succeeding processing to a liquor solution of approximately 50% $MgCl_2$. There is about ½ lb. of magnesium per barrel of sea water. A cubic mile of sea water will supply the Velasco and Freeport operations for 100 yr.



The granular magnesium chloride "cell feed" is conducted by the overhead conveyors and fed from the roof to each of the magnesium cells in these long buildings. Ample ventilation is provided through the stacks in the roof.

Lime from Oyster Shells

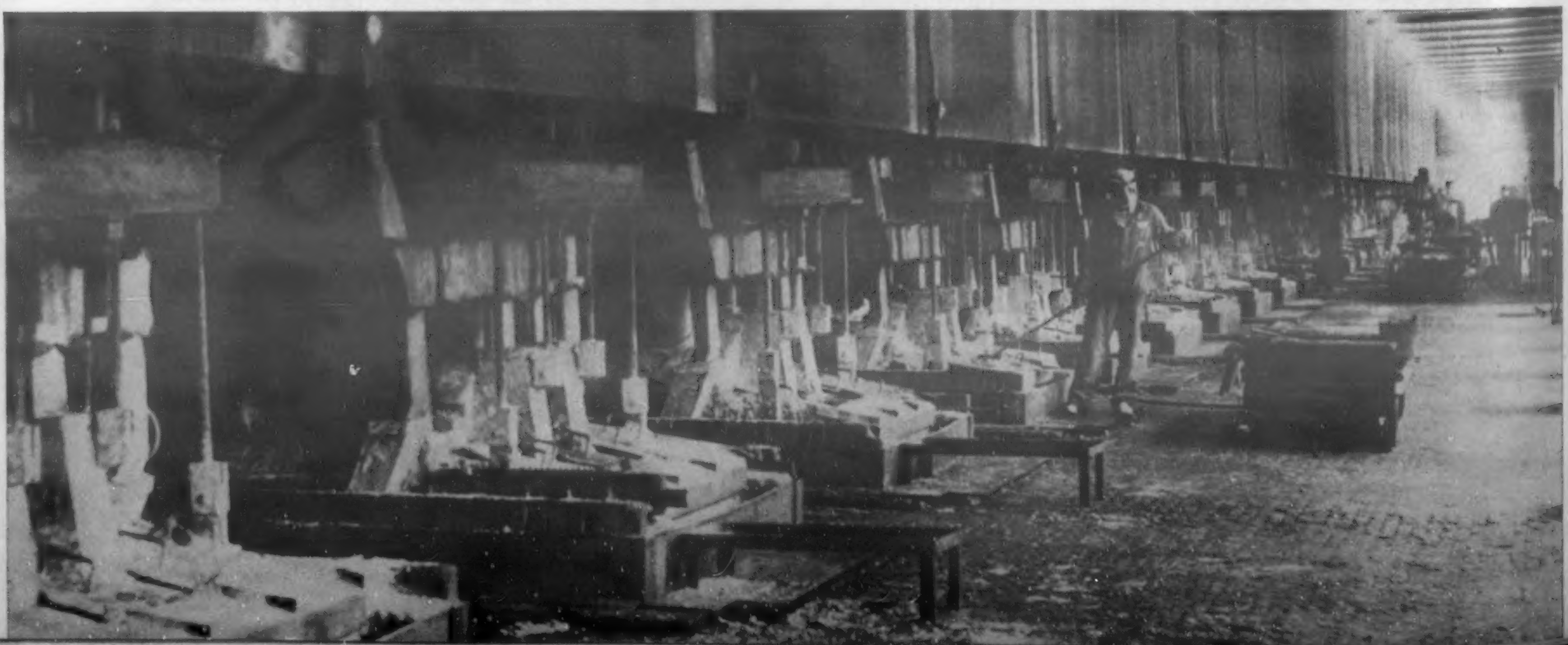
Lime is secured from oyster shells dredged from the reefs of Galveston Bay. Since there are many more surrounding reefs and bays, the everlastingness of Dow raw materials is again apparent. Brought in by barge, unloaded by shell scoops, the oyster shells are washed free of mud and salt and conveyed to shell storage. It requires about 2 lb. of shells per 1 lb. of lime. The Dow process uses about 500 tons of lime per day. A month's storage of 30,000 tons of oyster shells is maintained.

The washed oyster shells from storage are calcined in three Allis-Chalmers standard rotary lime kilns, fired by natural gas and completely controlled. All the accessories are beautifully set up, in keeping with the excellent housekeeping that is typical of Dow.

The reaction here is $CaCO_3 \longrightarrow CaO + CO_2$. An Allis-Chalmers slaker accommodates each lime kiln. The white, unslaked lime is dropped hot into the slaker, otherwise heat would have to be supplied, and it is quicker, more thorough and economic to use such hot slaking. By eliminating the stages of solid lime storage, Dow saves fuel, conveyors and storage.

The striking distinction of Dow practice is the manner in which it makes use of nature wherever possible. Water as transportation, lime from oysters, conveyance by gravity—everywhere possible, Dow works with nature. Solids are more difficult to handle than fluids and in its mining from the sea, Dow avoids solids wherever possible, although its ultimate quest is for that solid wonder metal, metallic magnesium. How fortunate it would be if coal or iron could be mined this way!

This interior view of the magnesium cell building shows the clean cut arrangement of the electrolytic cells. In the cell, magnesium chloride is electrolytically dissociated into magnesium metal and chlorine gas.



Boiling hot water and hot slaked lime are pumped to Dorr storage tanks 150 ft. dia. with a 14-ft. depth, which provide a means of thickening the dilute milk of lime by a settling process. The clear hot water flows off the top and back to the slaker to conserve heat, while the thickened, settled milk-of-lime is pumped from the bottom of the tanks to the flocculator where the lime slurry meets the sea water. The extended chemical reaction here is:

$$Ca(OH)_2 + MgCl_2 \longrightarrow Mg(OH)_2 + CaCl_2$$

Let us now trace the sea water flow up to this point. Peculiarly, the sea water strength and analysis the world over is approximately the same. It contains the same salt properties as the body fluid in proportion, but not concentration; proving, perhaps, that all humans were once poor fish. The barge canal is a good settling basin and the sea water arrives at the turning basin pumping station pretty well clarified. Five Worthington centrifugal pumps with a combined capacity of 350,000 g.p.m. pump the sea level ocean water into a 10 ft. elevated flume which might be called an open pipe line or storage basin 4000 ft. long x 20 ft. wide x 10 ft. deep. This sea water first passes through endless roller type Link-Belt screens, a sluice passing out the trash. Then the water is surged through special rotary tumble screens and into the sea water flume.

Making the Concentrated Magnesium Chloride

From this, sea water is pumped by pipe line at 30,000 g.p.m. into the flocculators where it mixes with the milk of lime slurry, carefully adjusted and controlled for right pH, to obtain the first major chemical reaction of:

$$MgCl_2 + Ca(OH)_2 \longrightarrow Mg(OH)_2\downarrow + CaCl_2$$

The suspended Mg $(OH)_2$ is settled out by gravity in earthwalled Dorr ponds which are 500 ft. sq., 14 ft. deep, and equipped with Dorr mechanisms, each 20 ft. dia. The spent sea water is decanted off the top of the Dorr ponds to the effluent waste canal and pumped into the river. The purpose of this flocculator treatment is to let the $Mg(OH)_2$ settle out, by means of the Dorr settling device, into a white, flocculent precipitate which is known as milk of magnesia in the drug store.

It is interesting to know that there are 43 other materials that could be taken out of this waste sea water, such as bromine, calcium chloride ($CaCl_2$) which approached commercial practicality, Epsom salts ($MgSO_4$), potassium chloride (KCl) for fertilizer, as well as such metals as copper, lithium, iron, aluminum, etc.

The $Mg(OH)_2$ slurry is pumped from the Dorr ponds by Dorrco diaphragm pumps into storage pits and forwarded to storage tanks 100 ft. in diam. x 40 ft. high. The precipitate contains still too much water and a filtration operation follows.

The $Mg(OH)_2$ slurry is filtered in Moore filters, consisting of cotton duck envelopes or leaves having spacer strips whose dimensions are 2 in. thick x 5 ft. long x 8 ft. wide, which are accumulated 100 leaves to a basket. These baskets are handled by overhead cranes. All equipment is Dow designed. A suction filter mechanism is installed into each Moore filter pit, into which the filter leaves are immersed, the basket being on I-beams with leaves suspended. Suction is applied to the inside of the leaf, pulling the sea water into and through the leaf, separating it from the $Mg(OH)_2$ which clings to the outside of the leaf as a cake 1 to 2 in. thick. This waste water is withdrawn and discarded. The pasty, cake-like precipitate of the outside leaf is moved by transferring the basket to the discharge pit where compressed air blows off the $Mg(OH)_2$ cake. It is then creamed with dilute $MgCl_2$ into a pumpable solution and is pumped to the neutralizers.

The neutralizers accomplish the further chemical reaction of:

$$Mg(OH)_2 + 2HCl \longrightarrow MgCl_2 + H_2O$$

At this point the $MgCl_2$ has gained about 30-fold in concentration. Two streams of HCl (20% solution) and $Mg(OH)_2$ are poured into two adjacent neutralizer tanks, 10 ft. dia. x 10 ft. high and intimately mixed. The mix is re-pumped to the Moore filters to remove all suspended impurities.

The $MgCl_2$ solution requires further concentration and undergoes a submerged combustion evaporization, using the principle of a submerged flame, like the action of an oxy-acetylene torch under water. Natural gas is burned in a bell shape burner immersed in a concrete tank 14 ft. dia., 12 ft. high. This is one of the early installations of submerged combustion, and the largest known. A carbureted mix of natural gas and air enters the burner through a narrow throat, the gas velocity being greater than the velocity of flame propagation. In the bell of the burner, the gaseous mixture expands until the velocity of the gas is below the velocity of flame propagation and combustion occurs at this transition point; the heat release being in the nature of 4,000,000 B.t.u. per hour per cu. ft.,

Magnesium metal floats to the top of the cell and is skimmed off by hand dipping. Here a metal dipper pours the 99.9% pure, silvery, molten magnesium metal into ingot molds.

as compared to 225,000 B.t.u. per cu. ft. in modern high pressure boilers. The consequent evaporization is 85% efficient. The four submerged combustion evaporators each contain four burners. This $MgCl_2$ solution is given a final polishing operation in Sperry filter presses and is forwarded to the shelf driers. At first hand, this seems like a lot of processing to arrive back to the $MgCl_2$ of the formula reaction with which we started out.

The procedure is, of course, to get $MgCl_2$ free from water. Normally, magnesium chloride in crystal form contains about half its weight of water, and if in that state it is introduced into an electrolytic cell, not only will much current be wasted in the decomposition, but a variety of undesirable chemical reactions will be set up. The $MgCl_2$ reacts with its own water of crystallization to become magnesium oxide, which involves the need for this advanced chemical processing by Dow.

Drying the Magnesium Chloride

The drying process is by Dow driers, 50 ft. in diam. and 50 ft. high which are similar to Hereshoff furnaces. Here the concentrated $MgCl_2$ is dried on shelves by hot air at 200 C. to complete the first stage of the chemical phenomenon, the resultant granular $MgCl_2$, about 85% anhydrous, being known as electrolytic "cell feed."

There are three such shelf furnaces, or driers, each having 12 shelves. The 10 upper shelves of each dryer accomplish preliminary dehydration and the two lower, the finish drying. Burners are Maxon Premix Venturi. Two fans of 150,000 c.f.m. service upper shelves, one fan of 40,000 c.f.m. the lower shelves. The 50% $MgCl_2$ concentrate from the boiling down kettles (evaporators) is pumped over a weir to measure its flow into a rotating kiln where it is fed with recycled material and returned to the shelf driers. The charging chute to the driers is at the center, and raker arms move it to the periphery and into collector chutes to the proportioners. Each shelf has a proportioner with a Star valve arrangement.

Production of the Metal by Electrolysis

From the shelf driers, the granular $MgCl_2$ is placed in a series of storage bins and an extensive system of conveyors distribute, proportion, and feed it to each of the Dow electrolytic cells. There are eight cell buildings containing 27 Dow cells, a total of 216 cells of rectangular shape, each producing about 1,000 lb. of magnesium per day. These are cast steel pots, properly refractoried. The granular $MgCl_2$ becomes a molten electrolyte in the cell itself and decomposes by electric current in the final chemical reaction:

$$Mg + Cl_2 \xrightarrow{\text{Electrolysis}} Mg + Cl_2$$

The Cl_2 is re-cycled as shown in the original formula and as later explained.

The electric current is passed between the carbon anodes and the cell pot which acts as cathode, the dip and straddle of the buss bars servicing each cell series representing very neat construction. By this electrolysis, metallic magnesium is resolved, floating to the surface of the molten cell bath where it is dipped at intervals by hand ladle into ingot molds, 99.9% pure Mg, the ingots weighing 18 lb. The chlorine gas bubbles up through the bath and is removed from the cells through a duct system to the HCl furnaces. Power is rectified in Westinghouse Rectifiers from 13,800 volts A.C. to 600 v. D.C. to accommodate this electrolysis.

An SO_2 atmosphere is employed in the molds during pouring to prevent burning of the magnesium. The pour is made, one dipper to the mold, through a ladle whose spout or lip is from the bottom, the uniformity of the pouring technique requiring a skilled steadiness. Portable carts accommodate the molds and the magnesium ingot, knocked-out in front of cell is ready for transportation to the alloy plant.

A chlorine plant is necessary to supply the chlorine makeup and to supply process losses. Cheap power and heat and abundant NaCl are the economic essentials. There are over 100 salt domes in the Gulf Coast area, and Dow has extensive brine wells on its property. It also has abundant natural gas and electrical power, maintaining a 120,000 kwhr. power plant. The chlorine loss in the process is supplied by a Hooker cell chlorine plant, the chlorine being manufactured from NaCl by electrolysis. The recycled chlorine from the electrolytic cells is burned with natural gas to form HCl, absorbed in H_2O and recycled to the neutralizers to complete the original equation:

$$MgCl_2 \xrightarrow{\text{Electrolysis}} Mg + Cl_2$$

$$2HCl \longleftarrow Cl_2 + H_2 \longleftarrow$$

$$CH_4 + 2H_2O \longrightarrow CO_2 + 3H_2$$

The CO_2 is thrown off into the atmosphere and the free hydrogen is stacked away high in the air. Sometimes lightning ignites it to become a burning beacon, symbolizing the Shenandoah's fate.

In the delicate business of putting magnesium cells into operation, cell feed was brought from Midland in cake form to season the cells in their melt before any Freeport feed was added. After successful operation for some weeks, an unfamiliar sludge appeared whose accumulation was expensive when removed by hand dipping. A drop in cell efficiency occurred. Finding it to be boron, after they had injected a bit of it in a Midland cell, the remedy was found to be extra lime in the dehydrating process which caused the boron to stay in solution and pass off with the waste water. Though some sludge develops in the Velasco operation, it is of minor consequence.

The Dow magnesium achievement has been a high public service which reflects the spirit and adventure of American enterprise at its best. Here is group intelligence, coordinated in a community of interest to the betterment of life. Here is constructive purpose and determination which has saved the progressive forces of the world from defeat. Have no doubt that when magnesium returns from war, it will take its place as a national necessity for the lightening of man's burden. The projection of the shadow of that 1887 test tube in the hands of Herbert H. Dow at Case, has now consummated a miraculous conception of great moment to the enjoyment of our future peace.

The first step in the forming of a cutting tool. The cutter is being blanked on a profile acetelyne torch by an employee of the Texas Division of North American Aviation, Inc., manufacturers at Dallas, Texas, of the P-51 Mustang fighter, AT-6 Texan combat trainer and B-24 Liberator bomber.

High Speed Milling

by **KENNETH MACKER** *North American Aviation, Inc., Dallas, Texas*

THE TEXAS DIVISION of North American Aviation, Inc., produces the famed Mustang, first military aircraft whose engineering was inspired by actual combat conditions; fastest-flying, most versatile of pursuit fighters, it is capable of hedge-hopping in ground strafing heights, too low for electronic detection, or dive bombing from 40,000 ft. altitudes at plus 425 m.p.h. speed. Better than 97% of its parts, exclusive of forgings and Government-furnished equipment, are fabricated in-plant at Dallas, Texas. The varied operations on the hydraulic parts of the landing gear assembly are the most precise of all machining jobs, at times reaching tolerances of 0.0001 in. Various metals are used—magnesium, duralumin, and chromium-molybdenum steel. This landing gear is entirely designed by N.A.A. for the P-51 Mustang.

Faster machine speeds, increased number of work pieces per grind, smoother surfaces, easier climb cuts, greater longevity of carbide tips with particular relation to better fortification against impact created in interrupted cuts—all caused N.A.A. to explore the possibilities of milling cutters set at negative rake.

The Texas Division's machine shop is a truly mammoth collection of the latest machine tools. Its tool making facilities are also complete. Harold F. Schwedes, division manager, is an able precisionist with a Sperry background and much accomplishment in tool engineering. J. B. Smith, general superintendent of Plant A, and W. F. Thies, superintendent of tooling, are accredited masters in tool design. This article on negative rake cutting is based upon interviews with them. Something of the theory, tool making practice, and machine operations are detailed.

ENGINEERING ACHIEVEMENTS

Few machining developments in recent years have been as spectacular in their production and cost benefits as the new and increasingly used practice of milling steel at very high speeds with carbide tools and negative rake angles. Higher production, better finish and lowered heat-distortion are the outstanding advantages—in some instances production increases of several hundred percent over ordinary milling practice using high-speed steel cutters have been recorded. A wartime engineering achievement primarily of West coast aircraft plants, the practice is spreading fast to alert shops throughout the country. This article outlines the principles involved and describes the application of the new practice to the high-speed milling of alloy steels and light metals at the plants of North American Aviation, Inc. —*The Editors*

Negative Rake Cutting Defined

Negative rake cutting is accomplished by a cutter whose inner edge is ahead of its outer edge. The action can be likened to a stroke of the hand in the sand. If the forward stroke is by the finger tips of the hand, they dig into the sand; the line of force of the stroke through fingers being backed largely only by the knuckle joints. But if the forward stroke is accomplished by the heel of the hand, the bite into the sand is a drag, the line of force flowing back through the wrist, back through the firm support of radius and ulna to where, stiff-armed, it is absorbed by the shoulder joint. The sand stroke by finger tips can be likened to positive, and that of heel of the hand to negative rake cutting. This is a popular illustration; a schematic representation of the principle will be found in a more technical accompanying drawing.

It is obvious that the negative cutting requires more power. It gives the bond of the tooth insert more chance to hold. It drives the tooth into compression with the body. It requires a heavier tool holder to accommodate. The tendency of the negative cutter is to drag, while the positive tends to dig. The negative requires greater rigidity. It effects a milder (if any) backlash. It has a stronger cutting edge to better withstand interrupted cutting impact. Its line of force tends to apply itself obtusely while the positive cut is applied acutely (the impact shock being set further back from the cutting edge of the tooth).

Negative cutting makes possible faster speeds and feeds which naturally require fewer teeth and give better chip clearance. Consequent smoother surface and higher polish are self-evident. Simpler tools can be employed. Longer tool life will result. In the negative cut, the chip starts at the outer edge and finishes at the point of the tooth. The exact reverse is the case with the positive cut. In climb cuts where the work is down against the machine, more metal can be cut per stroke.

As Smith of N.A.A. describes it, "with negative climb cuts, you beef in and hog out." Since the negative cutter walks in to take out the metal, it not only cuts faster but accomplishes a deeper cut. For this reason it is necessary to keep negative cutters on the shortest arbor and in closest connection to the work because of the strain on the arbor. Again, the reader is referred to the illustration of stroking the sand, and all the theory of negative radial rake cutting (the A. S. M. E. definition) will become clear as a simple principle, easily understood. Wonder is that it was "so long a-borning." It is aviation's revolutionary contribution to milling practice.

N.A.A. has the policy of engineering, designing, producing everything it can; testing equipment, machines, jigs and fixtures. The Texas Division makes all its thread and plug gages, a batch of 7,000 being observed running through production, one operation on a Jones & Lamson thread grinder, cooled by Servel, having 0.0001 in. limits. The design and making of tools is no exception.

Making the Milling Cutters

The urgency of military aircraft production and the demand for fabricating speed made it intolerable to wait for six weeks for milling cutters from outside tool makers which N.A.A. can produce in-plant in 3 hr. Nor could tool cost 300% greater than the average cost of $65 when building them itself be countenanced. So the Texas Division tooling has developed a technique of building its own milling cutters. Time required between boiler plate and milling machine is 150 min., no matter whether the cutter is 12 or 2 in. in diam. All red tape is eliminated.

Briefly, the N.A.A. tool making method on cutters is that the tool print is defined on sheet metal by prick punch and contoured into template by dual saw. The cutter body is of boiler plate. The template is pantographed and boiler plate body stock is cut to this pattern by acetylene torch. The blank is then submitted to a blanchard grinder to establish two flat surfaces, and the body then proceeds to the engine lathe to establish the center. Arbor holes are bored, key slots being omitted in the N.A.A. design. Cutters are held on arbors by friction grip rather than by a key. This is in particular consideration of the higher speed of negative cutting and to prevent stripping the teeth or springing the arbor in case the cutter stalled. This would happen if the key slot was employed.

The original body plate is 1 in. If it is necessary to take a cut from this, an undercut from the ½-in. bearing surface to throat is made by taking ⅛ in. off both sides.

The Smith philosophy in tool making was: "Our practical technique is to build the tool so simple, you know it won't work. Then add enough to make it work. Last and most important, 'beef' it."

After blanking, the cutter, manufactured in the tooling department at the Texas Division of North American Aviation, Inc., looks like this (left). In the second step of the series of operations, followed in the tooling department at the Texas Division, to prepare a cutting tool, the cutter is mounted on an arbor with the tip in the center position of the coil for brazing (right). This work is done on a Lepel induction brazing machine.

After the cutter body has been thus developed, it is placed on a mandrel and slots are milled for the insertion of teeth. N.A.A. uses hardened carbide tips. On the same mandrel, the work goes to the induction furnace where tips are brazed on. A special induction coil, designed to fit the locality of the tip, is used in this induction brazing. It is N.A.A. practice to place a 0.005 in. nickel layer between the tip and body filler, providing a much stronger anchor.

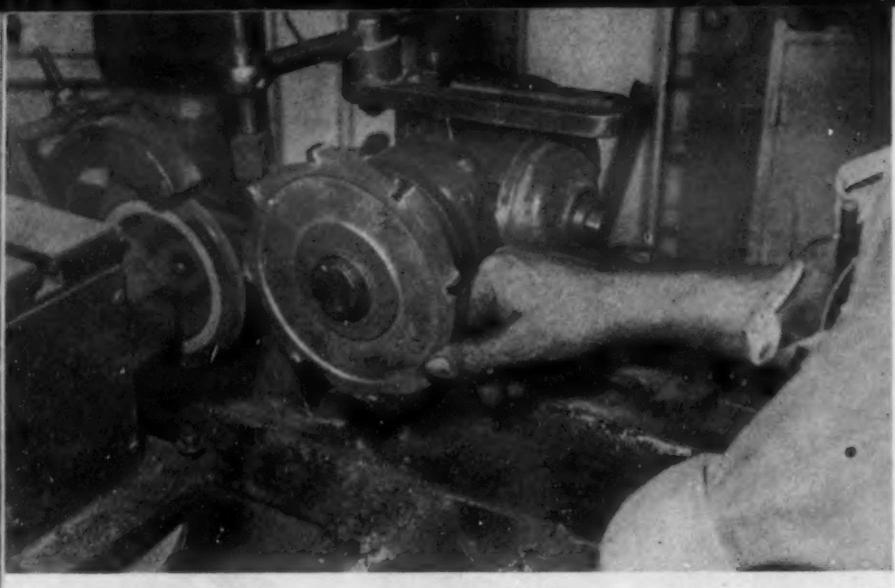
After induction brazing, the cutter with anchored tips is placed on the grinder and the negative rake angle of 10 deg. is ground. If the cut is to be on the face, the degree of the cutting angle is lowered 5 deg. Negative side cuts take a standard 10-deg. angle. One tooth per inch is the rule. Teeth can't be too close together, for if the feed is slow, the tooth won't have a chance to get under the metal and a burnishing effect will result. It is important to choose the right grade of tip relative to the metal being cut. N.A.A. has cut tool costs better than 300% and increased life 20 times over.

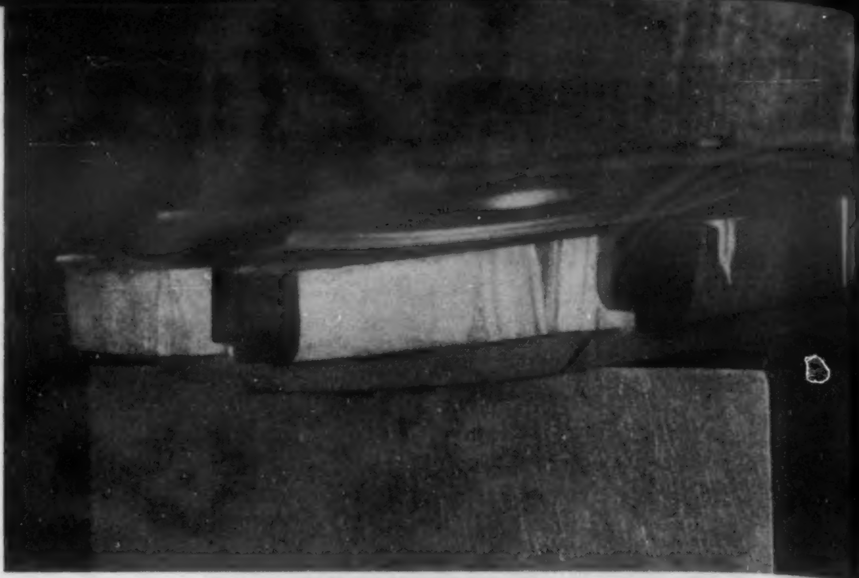
Performance on Specific Jobs

N.A.A. uses negative rake cutters on all varieties of machining, finding an astonishing increase in tooth life. The comparison is a life of 60-hr. negative to 3-hr. positive cutting. Straddle, slot and stagger teeth mills are all designed with negative rake.

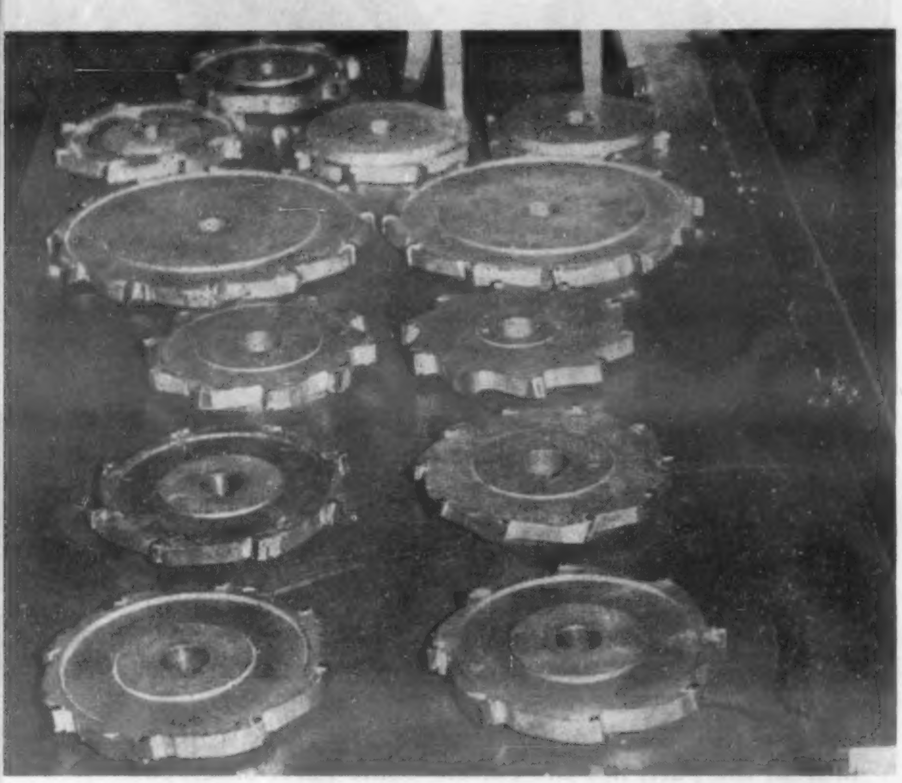
Negative cuts as deep as 0.020 in. are made totally unsatisfactory when positive rake is attempted. Coolants are used on all negative rake cutting to dissipate heat in the part, not the cutter. Some parts observed have a smoothness under 20 microinches. One vertical mill was observed, facing a chromium-molybdenum steel surface with a depth of negative cut between

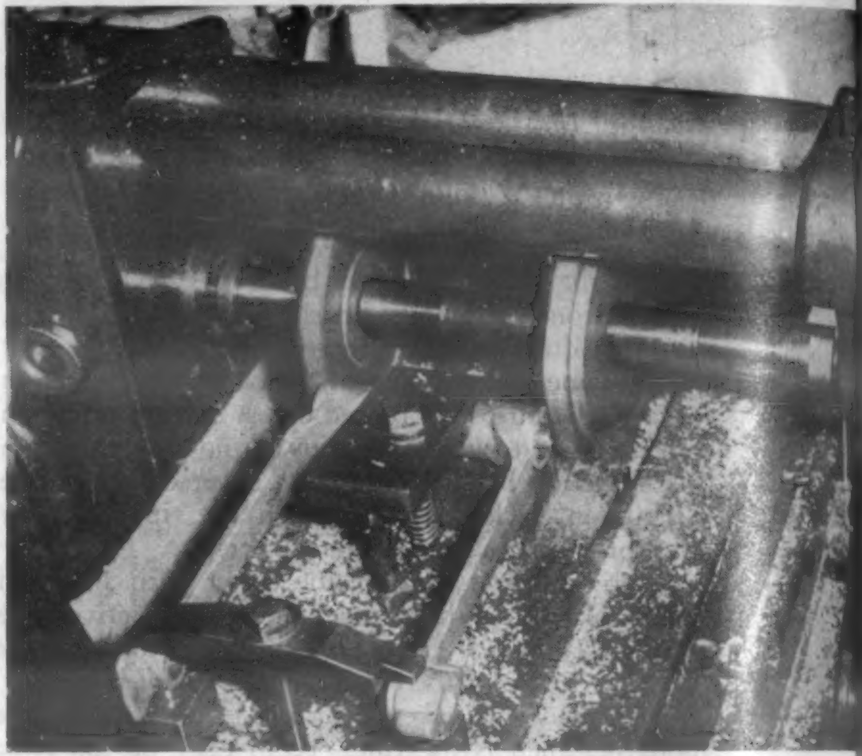
This photograph shows how the cutter is mounted on the arbor preparatory to placing it in a jig to weld in the tips.





At left the cutter is mounted on a Cincinnati tool cutter grinder in the tooling department. On this machine, the tips will be ground. Pictured right is the cutter complete with its tips and ready for use in the machine shop of the Texas Division of N.A.A. Inc.





A few of the various sized cutters made in the tooling departments at the Texas Division (left). Two of the cutters are shown at work (right) in the machine shop of one of N.A.A.'s Dallas plants. The part shown is a rudder fork for an AT-6 Texan combat trainer.

Another cutter bites into a chrome-moly steel forging for a North American AT-6 Texas landing gear in this photograph. This machining is done in the Texas Division's Dallas plants.

0.015 to 0.020 in., using a 20-in. f.p.m. at 1300 r.p.m. The same cutter, cutting 0.020 in. depth, disengaged from machine and fed by hand at 4000 r.p.m. on a 1 in. drill rod, developed red hot chips about 4 in. in length. This was using a 6-in. negative cutter with two teeth.

Some of the milling tended to squeal like a pig at the end of the cut, chips coming out straight and blue. There was no indication of burned edges. There is some thought that the negative cut may have a molten flow characteristic. The cut on some machines tends to spark pyrotechnically and burned chip edges are noticed. But N.A.A. believes not; the depth of the cut and the chip characteristics being accomplished by the nature of the negative principle and its line of force at such high speed smoothly shaving the chip from the outer edge of the tooth over the tip.

Some examples of N.A.A. negative rake cutting are illustrated. Among them was the finish machining of a slot on a heat-treated chromium-molybdenum steel lock forging, part of the P-51 Mustang landing gear assembly. This was being accomplished on a No. 3 Cincinnati milling machine at 123 r.p.m., 1.75 ft. per min. using an 8-in. slot mill with 16 teeth, the work running in an oil coolant. Another was the facing of a magnesium tail-wheel housing, on a No. 3 Cincinnati at 450 r.p.m. with 3.625 ft. per min. using an 8-in. 2-tooth cutter.

Another operation on a duralumin motor mount forging used a stagger tooth 12-in. saw on a No. 3 Cincinnati, turning 96 r.p.m. with 2.125 ft. per min. Another operation was saddle cutting the end of another duralumin motor mount forging, the forgings being cut just enough to require locating from center hole; surface speed was 16 in. per min. at 388 r.p.m., using a 6-in. slot cutter on a Cincinnati No. 2.

Machining the base of a duralumin aileron hinge bracket on a Cincinnati No. 2 used an 8-in. 2-tooth cutter, though slots were arranged for four teeth, with 1200 r.p.m. and 12-in. per min.

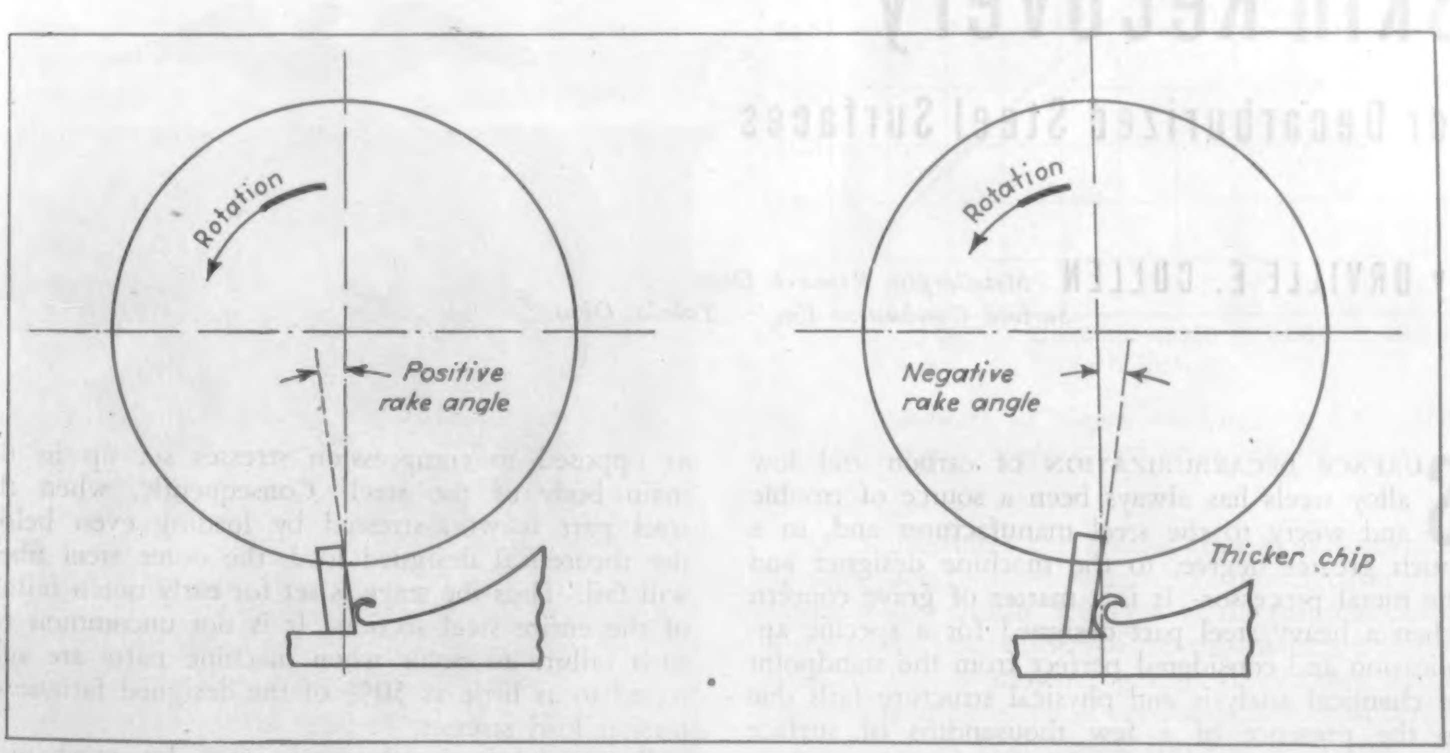
A 24 ST aluminum I-beam extrusion was being machined at 2000 r.p.m., 30-in. per min., using a 12-in. 12-tooth straddle mill.

A final operation was on a Cincinnati No. 3 with vertical head and an interesting built-up jig. This used a four-negative-rake-tooth 8-in. fly cutter at 2.75 ft. per min. and 180 r.p.m. to mill a duralumin motor mount face.

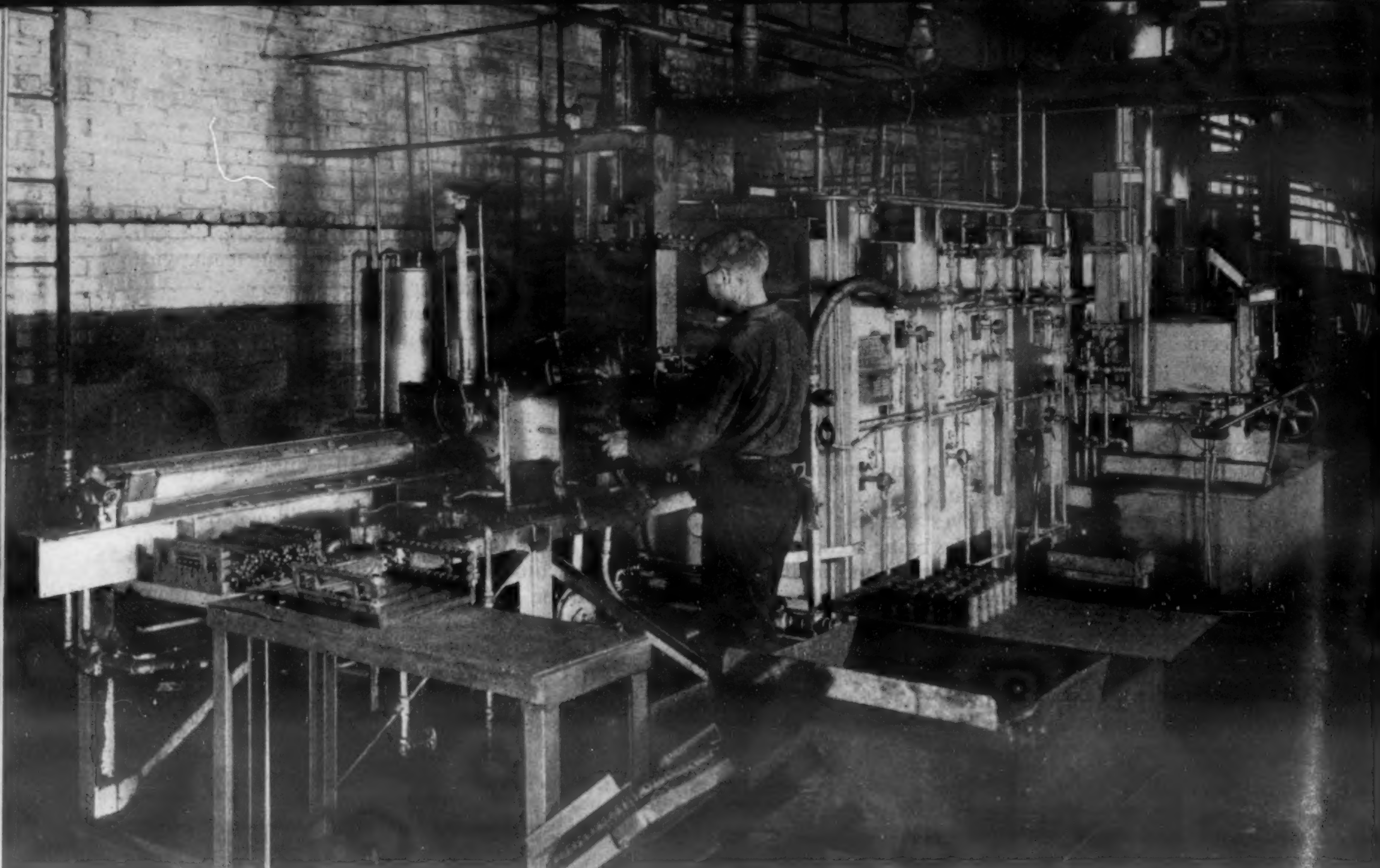
One advantage in being able to build negative rake cutters in 150 min. is that tools can be designed to fit available machines. The only thing that causes an idle machine in the N.A.A. shop is absenteeism. So many advantages are inherent in this milling cutter that the technique is being extended wherever possible.

A high cycle attachment to mill B-24 Liberator center section aluminum motor mount pads to an 0.005-in. surface tolerance relative to the chord-line of the wing is used. This employed a 2-tooth, positively raked carbide tool bit fly cutter, cutting at an angle, and at 10,800 r.p.m., with from 20" to 50" f.p.m. It is another tool making achievement, but that is another story.

Aviation has certainly introduced a spectacular innovation in milling practice. Among the manufacturing plants in that field the urgency of war is stepmother to invention. And this particular invention appears to have a brilliant future, especially if we may count on a continuing development of improved cutting materials to permit ever-higher machining speeds, for at the higher speeds the power consumption relative to positive rake cutting becomes proportionately lower.



The action of positive and negative rake milling cutters on the work is shown here. With the positive angle the chip load bears directly on the cutting edge of the carbide tip; with the negative-angle cutter, the cutting force is applied to the tip at a distance from the edge about equal to the thickness of the ship. (From a paper by H. A. Frommelt of Kearney & Tvecker Corp., presented at Westinghouse's Machine Tool Electrification Forum.)



For small parts and for limited production, this continuous pusher type muffle furnace can be used for carbon skin recovery treatment.

Skin Recovery

for Decarburized Steel Surfaces

by ORVILLE E. CULLEN *Metallurgist, Research Dept. Surface Combustion Co. Toledo, Ohio*

SURFACE DECARBURIZATION of carbon and low alloy steels has always been a source of trouble and worry to the steel manufacturer and, in a much greater degree, to the machine designer and the metal processor. It is a matter of grave concern when a heavy steel part designed for a specific application and considered perfect from the standpoint of chemical analysis and physical structure fails due to the presence of a few thousandths of surface decarburization.

The notch effect of surface decarburization has been the subject of extensive study. It is well agreed that the heat treatment of steel parts results in setting up tension stresses in the outer decarburized areas as opposed to compression stresses set up in the main body of the steel. Consequently, when the steel part is work-stressed by loading even below the theoretical designed load, the outer steel fibers will fail. Thus the stage is set for early notch failure of the entire steel section. It is not uncommon for such failure to occur when machine parts are subjected to as little as 50% of the designed fatigue or torsion load stresses.

Removal of decarburized areas by mechanical means is one method of raising the endurance limit of the steel. Applying compressive stress to the decarburized surfaces by peening or shot blasting is another helpful treatment. In the former case, proper

dimensional allowances must be made to take care of the maximum decarburization which may occur. Oftentimes this is difficult to predict. In any event, machining for no other reason than to eliminate decarburization is wasteful of time and material and in many cases may not completely remove the decarburized areas.

It will also be appreciated that the above-described treatments have their distinct limitations. One of these is the inaccessibility of some surfaces to these mechanical operations. Thus, for example, the inside of aircraft tubing, bolts and nuts, and odd shape forgings present difficult problems for either machining or peening.

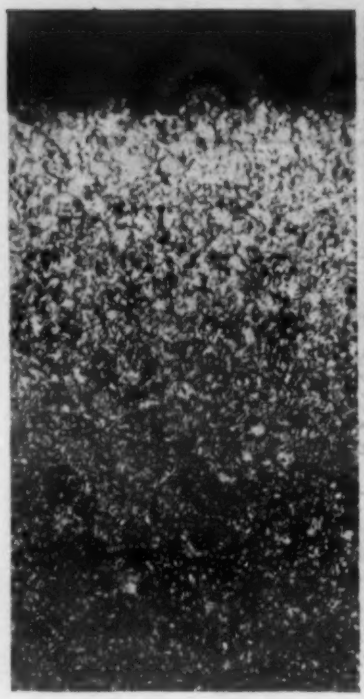
The Skin Recovery Process

Another method of surface treatment comprises restoring carbon to the depleted surface by a newly developed process. This involves heat treatment in a controlled atmosphere which is so regulated as to bring about the desired results. This process is known as "Skin Recovery".

Investigation proved that in many cases final heat treatments were being carried out in atmospheres which were substantially neutral, hence should neither carburize nor decarburize. Unfortunately, previous heating operations had caused decarburization of the surface layers and the condition would not be erased in the final treatment. This is aptly illustrated in the photomicrograph Fig. 1 showing the heavily decarburized edge of an SAE 4140 steel forging after normal hardening and tempering treatment. In this case as in many others, close tolerances, surface finish and the contours of the part precluded any possibility of machining or peening.

ENGINEERING ACHIEVEMENTS

Decarburization has probably brought more headaches to heat treaters, metallurgists and steel manufacturers (all of whom are charged with preventing it), to engineers (who must design and use parts in spite of it), and to production executives (who have to pay for removing it) than any other problem associated with heat treating. It is therefore no mean achievement to have developed a method of restoring the carbon to the surface of steel and steel parts that have been decarburized at some stage of their production. Mr. Cullen describes such a method, called "skin recovery"—a simple controlled atmosphere process based on the principle of carbon pressure balance, and shows how it is being applied today to the recarburizing of various engineering steels. —*The Editors*



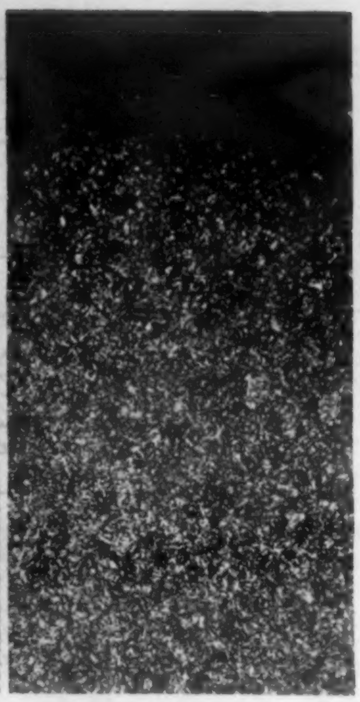


Fig. 1. An SAE 4140 forging showing decarburized edge after normal heat treatment. 100X.

Fig. 2. An SAE 4140 forging (same as Fig. 1) after skin recovery. 100X.

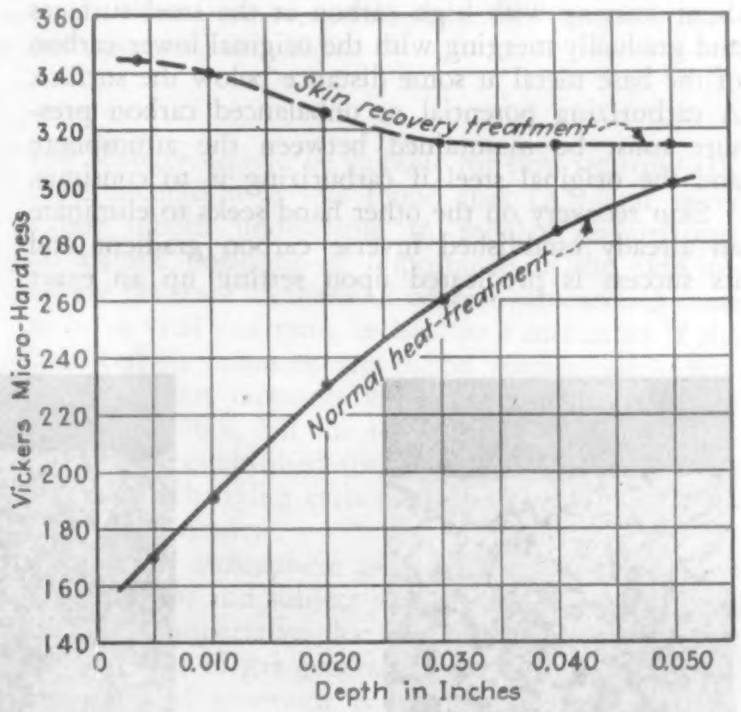


Fig. 3. Hardness vs. depth readings on SAE 4140 steel forgings before and after skin recovery.

Fig. 2 illustrates the results after skin recovering the same decarburized forging. Carbon recovery was complete and within ±0.03% of the original carbon in the steel. The benefits of the treatment are emphasized in Fig. 3 showing graphs of Vickers Microhardness reading taken at various points from surface to core of fully heat-treated forgings with and without benefit of skin recovery. As would be expected forgings receiving the treatment have shown no signs of failure due to surface conditions. This was in sharp contrast to the high mortality rate observed before the application of this skin recovery process.

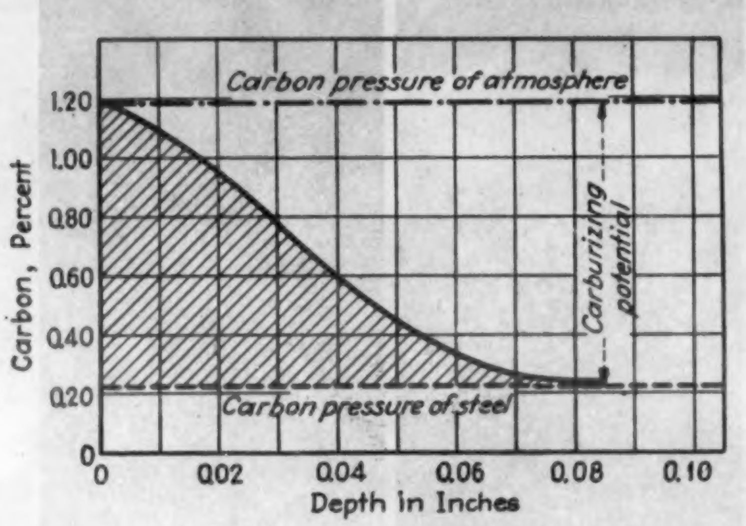


Fig. 4. Typical carburizing curve showing unbalanced carbon concentration from surface to core metal.

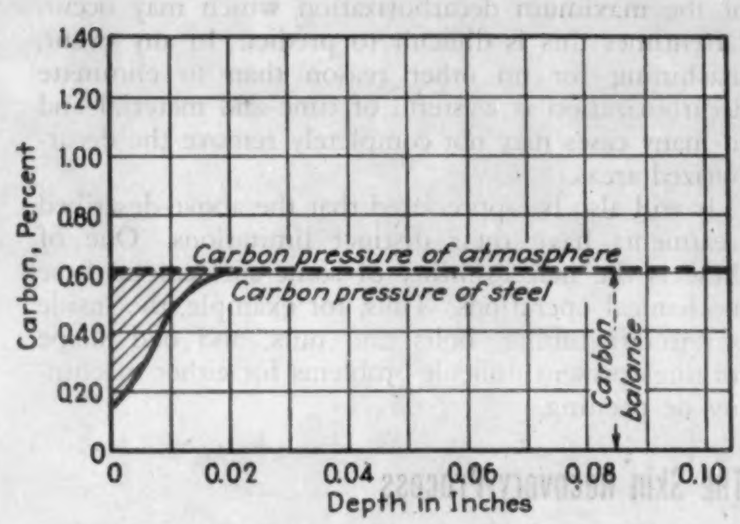


Fig. 5. Typical skin recovery curve showing balanced carbon concentration from surface to core metal.

Development of the Process

The development of the skin recovery process presented problems which had not been encountered in normal carburizing practice. Basically, carburizing is a treatment for establishing a definite carbon gradient starting with high carbon at the steel surfaces and gradually merging with the original lower carbon of the base metal at some distance below the surface. A carburizing potential or unbalanced carbon pressure must be maintained between the atmosphere and the original steel if carburizing is to continue.

Skin recovery on the other hand seeks to eliminate an already established inverse carbon gradient and its success is predicated upon setting up an exact carbon pressure balance between the atmosphere and the original carbon in the steel. Figs. 4 and 5 graphically illustrate the fundamental differences between carburizing and skin recovery. The shaded areas represent the carbon added by the two treatments.

In carburizing, depth of penetration is a function of time and temperature. In skin recovery carbon penetration at any particular point ceases when a carbon balance is reached between atmosphere and steel, and thereafter time has no effect. In other words, the treatment can be long enough to take care of the deepest decarburization without danger of increasing or decreasing the carbon content of those surfaces which were free from decarburization at the start of the treatment.

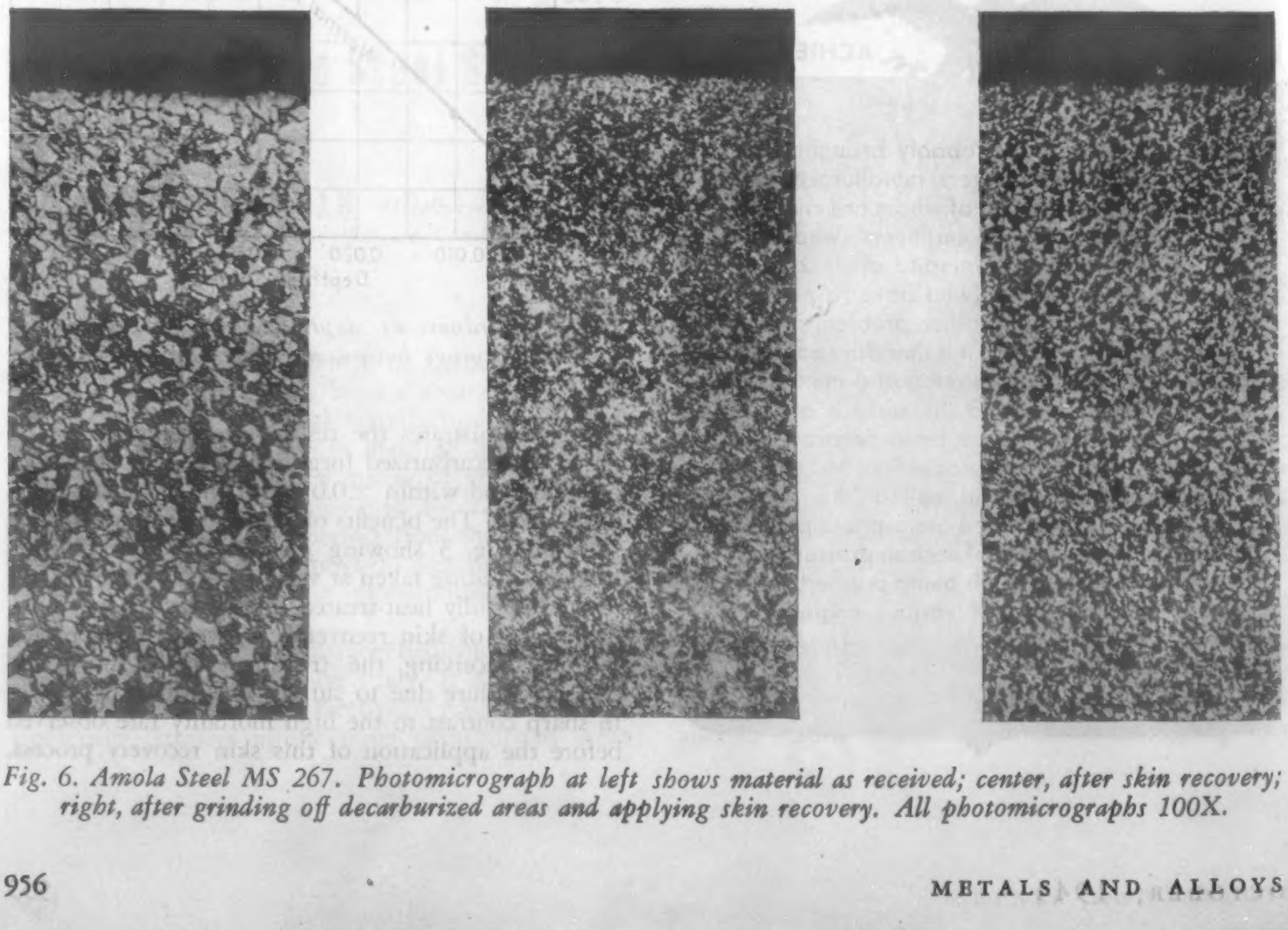
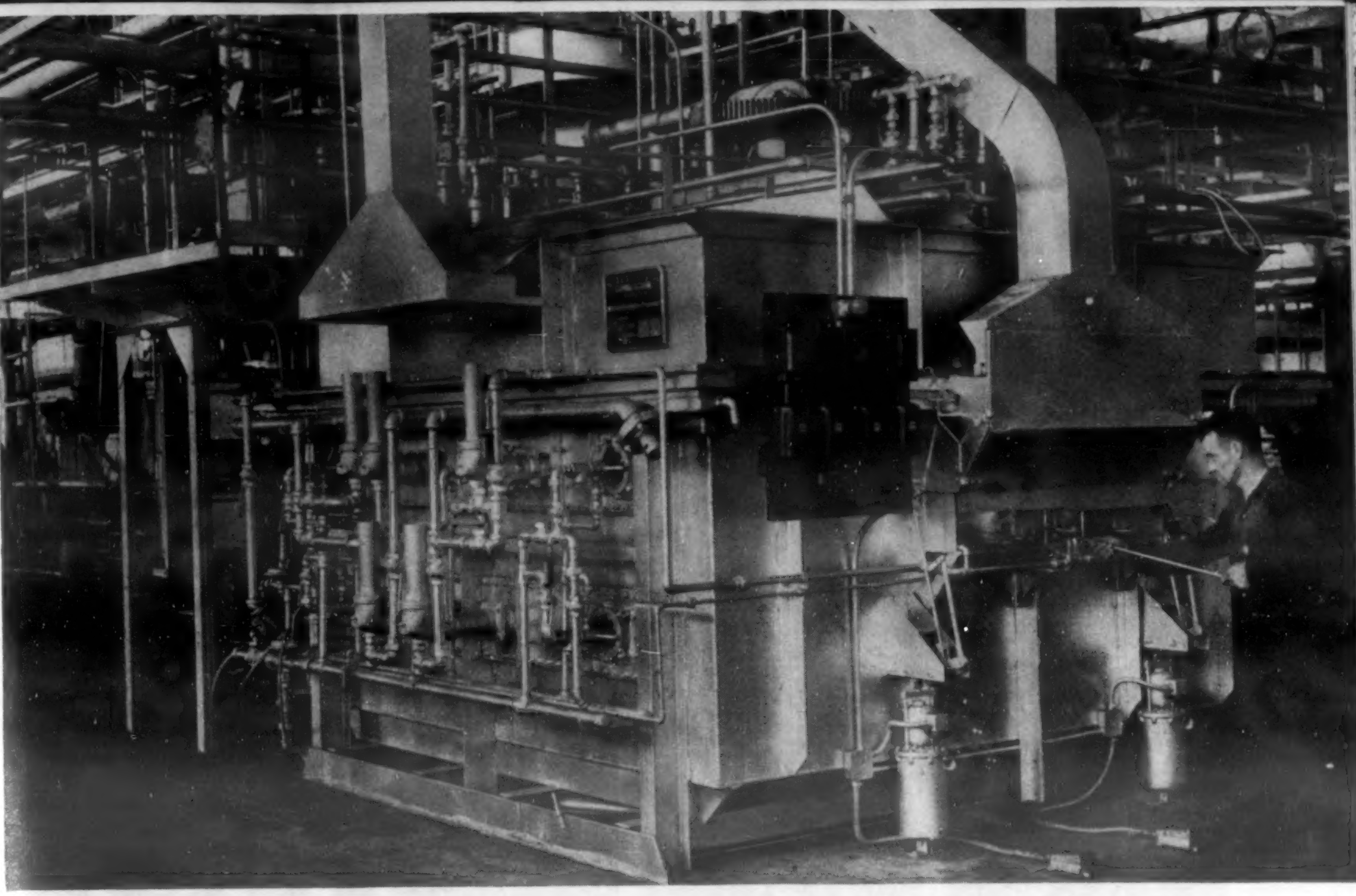


Fig. 6. Amola Steel MS 267. Photomicrograph at left shows material as received; center, after skin recovery; right, after grinding off decarburized areas and applying skin recovery. All photomicrographs 100X.



Certain types of work are best handled in rotary hearth furnaces. Work enters and leaves at the same station, cutting down on floor space and operating attention.

This point is clearly illustrated in Fig. 6. Amola M267 bolt stock exhibited approximately 0.006 in. decarburization in the as-received condition. By skin recovery the original carbon was completely restored to the decarburized surface. For comparative purposes, a portion of the original bar was ground to remove all surface decarburization and was then subjected to the same skin recovery treatment. As shown in the last photomicrograph, Fig. 6, neither carburization nor decarburization had occurred in this instance.

One commercial application of skin recovery involved salvaging a large quantity of heat-treated SAE 4140 steel bolts. Specifications called for a final hardness of 46-50 Rockwell C., but a large number of regularly heat-treated bolts were rejected because of soft surface conditions. Investigation showed that much of the original spheroidized stock was decarburized to a depth of approximately 0.005 in., and this decarburization had persisted throughout the final heat treatment.

The hardening furnace atmosphere was adjusted to provide a correct carbon balance and the rejected bolts reheated along with those coming from the production line. All the bolts thus treated passed inspection with final hardness reading of 47-49 Rockwell C., and thus potential scrap was saved to perform its particular job in the present emergency. Maintaining a skin recovery atmosphere in the furnace during the final heating for hardening has completely eliminated the rejection of bolts due to decarburization.

Atmosphere Control

In view of the problem involved it was apparent that present gas carburizing atmospheres, with some few changes, should be suitable for skin recovery. By experimentation it was found that CO_2 and water vapor, (both undesirable in regular carburizing) do assume positions of importance in the skin recovery process. Methane of other hydrocarbons cease to be as vital and must be held to a minimum if the best carbon balances are to be maintained. Optimum gaseous mixtures vary with temperature and carbon pressure, but the ratios of CO_2, CO, H_2 and H_2O, once established for a given temperature, will give an unchanging carbon pressure with readily reproducible results.

Since the atmosphere gas used for skin recovery is so important and subject to such close limits of control, it is imperative that the gas be prepared in a suitable type of gas generating unit. A most satisfactory type of generator is one employing externally heated reaction tubes which contain a catalytic material. Mixture of air and hydrocarbon gases heated in the presence of the catalyst are quickly and completely reformed to supply an atmosphere in which carbon dioxide and water vapor, as well as residual methane, can be controlled to any desired degree. This is most important, since the carbon balance of the furnace atmosphere is in turn controlled by the amounts of these constituents. The generator can be set to produce the gaseous mixture required for any particular carbon in the steel and will automatically maintain this mixture and carbon pressure balance until changed by the operator. The generator supplies all the atmospheric requirements of the heating chamber. Therefore, when change in carbon pressure is necessary, the operator makes the change by simply resetting the air-gas ratio control on the gas making unit.

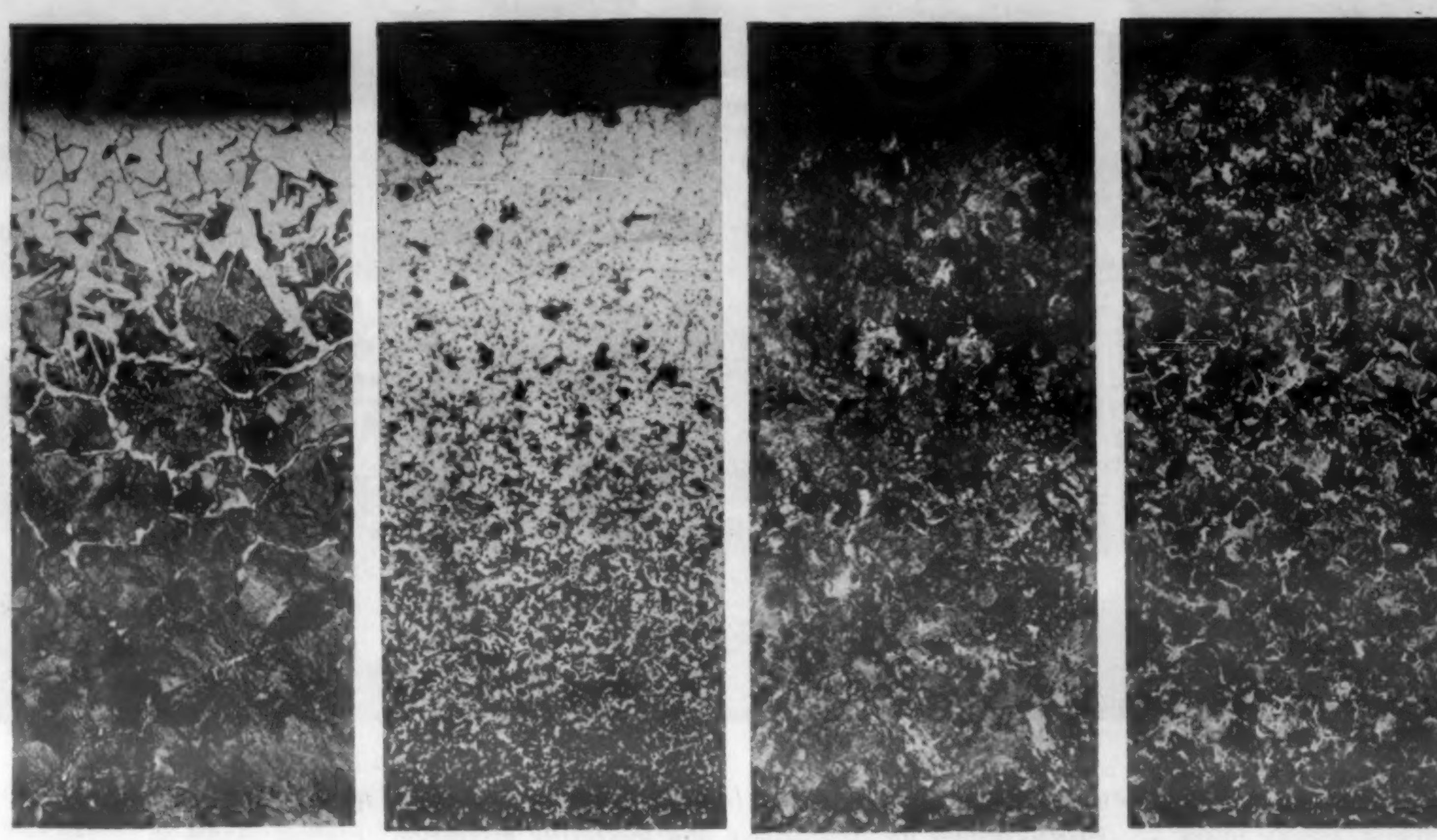


Fig. 7. (Left) An SAE 1095 rod as received for heat treatment. 100X. Fig. 8. (Center left) An SAE 9260 rod as received for heat treatment. 100X. Fig. 9. (Center right) An SAE 1095 rod after skin recovery. 100X. Fig. 10. (Right) An SAE 9260 rod after skin recovery. 100X.

The carbon pressure balance of the furnace atmosphere may be checked periodically by means of a test involving heat treating a small coil of fine wire and determining the final carbon content by weight changes. This method has proved to be a simple operation and shows a degree of accuracy well within the limits allowed for the more time consuming chemical analysis.

Applicable to Most Steels

Illustrative of the treatment of medium and higher carbon steel, Figs. 7 and 8 show decarburized structures of SAE 1095 and 9260 steels respectively, and Figs. 9 and 10 show the same steels after skin recovery has been employed. Various other types of decarburized carbon and low alloy steels have been subjected to the treatment, and the results have been uniformly successful. SAE 3140, 4130, 5145, 6145 and NE 9440 have been checked with good results, and there is no reason for believing the treatment could not be applied to any steel when re-carburization is required.

To date there is no evidence that carbon balance between the atmosphere and the carbon in the steel is affected by the other alloying elements which may be present. This undoubtedly holds true up to the austenite saturation value for any particular steel. Fortunately recarburization is usually carried on below this value. Some alloying elements, particularly nickel, slow down the penetration rate somewhat, and this must be allowed for in figuring heating times for complete recovery of decarburized areas.

The time of treatment is, of course, governed by the original maximum depth of decarburization and the temperature. As in carburizing, rate of carbon diffusion is greatly accelerated by increased temperature. Therefore, the treatment is preferably carried out at the highest temperature the projected use for the steel will allow. Generally speaking, the rate of penetration is considerably slower than in regular carburizing, this being due to the absence of any appreciable carbon gredient or "head" during the treatment.

In many cases where decarburization is not excessive, it is possible to combine the skin recovery treatment with heating for final hardening. In this way an extra operation is avoided, and the added costs of skin recovery are held to a minimum.

The skin recovery treatment is adaptable for use with either batch type or continuous furnaces. The chief requirement is that the work be heated in a chamber suitable for complete exclusion of both air and flue gas. Modern carburizing and clean hardening furnaces are admirably adapted to this use.

It is anticipated that in the near future, controlled atmospheres of carefully balanced carbon potential will be much more extensively used than at present. Not only will they find application in the final stages of heat-treating as is now the case, but on a much larger scale in all heating operations beginning with the pouring of the molten metal. Such uses of balanced atmospheres are not beyond the reach of steel manufacturers, and the pioneering work on skin recovery may well serve to increase the interest in surface carbon control throughout the steel making industry.

Adhesives for Metals and Nonmetals

by KENNETH ROSE   METALS AND ALLOYS

IN THE FUTURE, it seems that wood will have to share with metals one of its advantages as a material of construction. Metals, too, can now be joined strongly, safely, and durably by "gluing." Not only can metals be bonded to each other, but they can be securely joined to wood, glass, rubber, plastics, etc., or these materials can be joined among themselves in a wide range of combinations. A new group of adhesives makes possible this development.

Possibilities for new engineering materials are obvious. The engineer will have at his disposal wood with a metal facing to resist abrasion, metal with a rubber component to prevent transmission of vibration, thermosetting plastics to which elaborately molded thermoplastic parts can be joined, complicated forms in glass made by gluing together various components, and many others.

The adhesives themselves are now being produced by a number of companies, under different trade names. Most of them are basically similar—a rubbery constituent combined with a synthetic resin. Compositions are secret until the war has ended, as are certain test data and methods of use. Chrysler Corp. has Cycleweld, United States Stoneware has Reanite, Goodyear Rubber Co. offers Pliobond, Durite Plastics produces Durite S-3024 cement, Consolidated Vultee Aircraft Corp. offers Metlbond, B. F. Goodrich has Plastilock 500, and so on.

While all of these adhesives are new, they are not all, strictly speaking, war developments. Several had been introduced before the outbreak of hostilities while others were just coming out of the laboratory.

Perhaps the first rather futile "liquid solders" will be recalled—viscous nitrocellulose lacquers contain-

Applying Cycleweld adhesive to parts for glider ski pedestals. Courtesy: Chrysler Corp.

ENGINEERING ACHIEVEMENTS

One achievement of recent years that bids fair to belie its purely "processing" origin and become of major importance to materials engineers as well is the development and growing use of organic cements or adhesives for joining metals to each other or to non-metallic materials like wood, plastics, rubber, glass, etc. Satisfactory joint strengths are obtained, often in applications that once involved welding, but beyond that the adhesive-bonding methods and compounds are responsible for the creation of an entirely new group of composite materials of construction, combining in each case the surface wear resistance or body-strength of a metal with the lightness or vibration damping or color or corrosion resistance of a nonmetal. A number of companies and products are now serving this field, and in this article Mr. Rose classifies and describes the most important of these and indicates their present and future uses, possibilities and limitations. *—The Editors*

ing powdered aluminum to give a metallic appearance. These appeared in retail stores more than 10 yr. ago, advertised as metal-bonding materials. They had nothing in common chemically with the present adhesives, and failed to achieve widespread industrial acceptance. In 1937 United States Stoneware received the basic patents upon Reanite, the first of the metal adhesives to obtain recognition. In 1938 Chrysler Corp. started use of an adhesive cement, the forerunner of Cycleweld adhesive, to fasten insulating material to the interiors of automobile roofs. By 1940 Chrysler was utilizing an improved cement to hold together many car parts. By the following year developments had so improved the cement that bonds made with it were twice as strong as formerly.

Reanite adhesive was greatly improved also, but since rubber latex, a high-priority material, was required in its manufacture its uses could not be expanded as widely as might have been possible otherwise.

Other adhesives of this type are outgrowths of the plastic industry, or of the mushrooming aircraft industry.

Cycleweld, Cyclebond and Pliobond

S. Gordon Saunders, research engineer with the Chrysler Corp., is credited with the development of the Cycleweld process. Goodyear Tire and Rubber Co., supplying some of the raw materials used, was commissioned to make the adhesive. It is produced in two forms—as a tape, or as a fluid to be applied by spray gun, flow gun, or spreader. The tape does not wet the materials being joined as well as the fluid adhesive, but is more easily handled and dries quicker. Thorough cleaning of the surfaces is necessary.

The process is now available in three modifications. The original Cycleweld process is used for most metal-to-metal, wood-to-metal, rubber-to-steel, and plastics-to-plastics combinations, as well as for joining plastics to other materials. Heat and pressure must be applied to form the bond. The Cycleweld adhesive is considered as a thermosetting plastic, and the pressure need not be maintained during cooling after the material has been cured.

Where temperatures must be kept lower, a second modification, low temperature Cyclebonding, may be used. It is especially useful for joining dissimilar materials when one of them is wood, so avoiding warpage and other ill effects of high temperatures. In metal-to-wood joints, the metal surfaces are prepared with Cycleweld adhesive, and this adhesive is subjected to the usual curing cycle. The wood member and the cured adhesive on the metal are then spread with a Cyclebond cement and brought together with pressure and a low heat.

A third variation of the process is used where temperatures need not be held to the low range, but pressures must be limited. Irregular work, not easily held in presses, or parts having uneven surfaces, are typical subjects. Both surfaces are treated with Cycleweld cement, the material is cured as usual, and a Cyclebond cement not requiring pressure is used to complete the joint.

The composition of Pliobond is the same as that of the Cycleweld adhesive, Pliobond being Goodyear's trade name for the material. These adhesives have been approved by the Army Air Forces for certain aircraft construction. Strengths claimed for the bonds are higher than those for riveted joints.

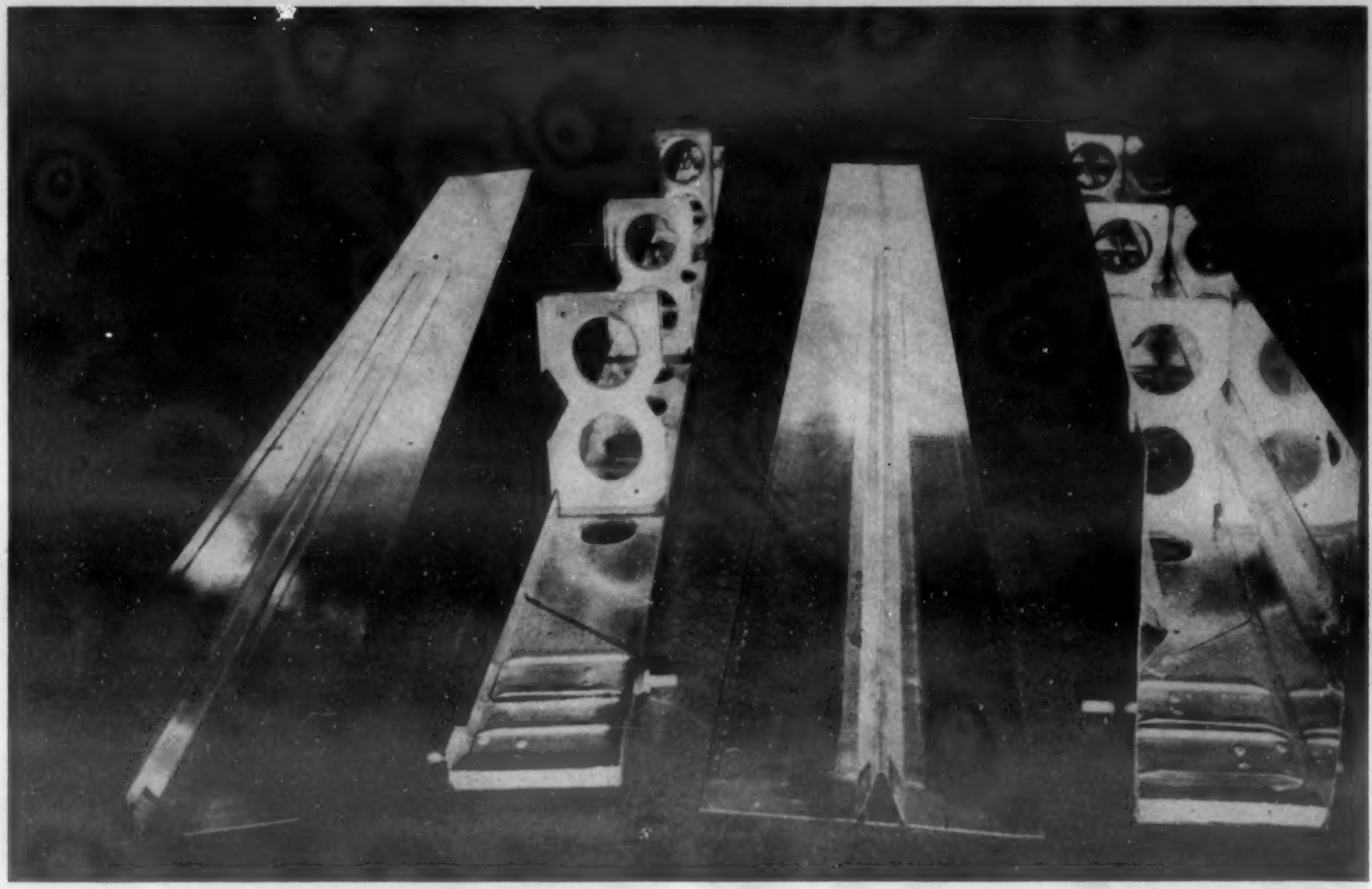
Reanite Bonding

Reanite bonding also is suitable for almost all metals, natural rubber, most of the synthetic rubbers, plastics, wood, glass, and ceramics. Several modifications are available for various combinations. Metal-to-metal bonds have shown shear strengths up to about 3000 p.s.i., while metal-to-rubber bonds have tested as high as 1200 p.s.i. in tension. The cement may be applied as a tape, or by brush, spray, or dipping. Applications of liquid cement will require about an hour for drying. Mild heat and low pressure are required for the curing cycle, which may require from 15 min. to 2 hr. Pressure should be maintained until the work cools, although water quenching may be used to hasten cooling at some sacrifice of strength.

Reanite bonds have maintained their strength at temperatures from 0 to 200 F. At temperatures from 0 to —50 F. and 200 to 300 F. slight loss of strength occurs.

A flow gun lays down the adhesive on the skin of a wing flap. Courtesy: Chrysler Corp.

A wing bulkhead assembly joined with Metlbond. The dark spots are rivet holes that would be necessary if the assembly were riveted. Courtesy: Consolidated Vultee Aircraft Corp.



The stabilizer midsection assembly for a P-40 pursuit plane, showing skin and stringer combination, web and bulkhead assembly.

Metlbond Adhesives

The search for a joining method for aircraft materials that would not cause bulging of the metal skin as did riveting and spot welding led to the development of the Metlbond adhesives. Aerodynamics engineers asked for a continuous bond between surfaces to improve airflow characteristics. Consolidated Vultee design and development engineers produced these metal-to-metal cements.

Requirements were exacting. The joining process must have adequate shear strength. Metlbonds give strengths as high as 3000 p.s.i. as compared with an average of 1800 p.s.i. for riveted construction. Sufficient flexibility to withstand impact loads was demanded. Resistance to heat and cold, salt water corrosion, aging, and fatigue was needed.

Various types of materials were tried. Thermosetting plastics were too brittle, thermoplastic resin cements tended to soften. Combinations of thermosetting resins combined with synthetic rubbers gave adhesives suitable for use except that high curing pressures and expensive jigs were needed. Consolidated Vultee then developed its synthetic rubber-plastic type cement, with satisfactory physical properties and low curing pressures.

Impact and peel resistance of the Metlbonds are reported to be practically constant from —70 to 160 F. They have been accepted by the Army Air Forces for assembly of many aircraft parts.

The Metlbond process makes use of a number of two-component cements employing synthetic rubber and plastic bases. A high pressure, high temperature, single phase cement may be sprayed onto the parts to be bonded, and cured at 330 F. for 20 min. under 100 p.s.i. A low pressure, high temperature, two phase type requires 15 p.s.i. pressure at 330 F. for 20 min., the rubber component being sprayed on and the plastic component applied by brushing. Two types of tape, one requiring 250 F., the other 330 F., and 100 p.s.i. are available. Finally, there is a very low pressure, high temperature cement requiring only one p.s.i., and a temperature of 330 F. This last produces a shear strength about two-thirds that of the first two types.

Developed primarily for the aluminum alloys, these adhesives can join successfully a wide variety of solids, including cadmium, zinc, magnesium, fibrous glass, cotton, rayon, wood, natural and synthetic rubbers, and several plastics. All of these cannot be bonded by one process, however.

Durite Cement

Durite cement is not, according to its makers, a rubber-plastic type adhesive. Shear strengths on metal-to-metal joints are of the order of 4,000 to 5,500 p.s.i. The material is not recommended for glass, wood, porcelain, cellulosic materials, natural rubber, certain synthetic rubbers and some types of plastics. It will join aluminum, aluminum and magnesium alloys, brass, copper, iron, and stainless steel, a number of thermoplastic and thermosetting resins, asbestos, and abrasives.

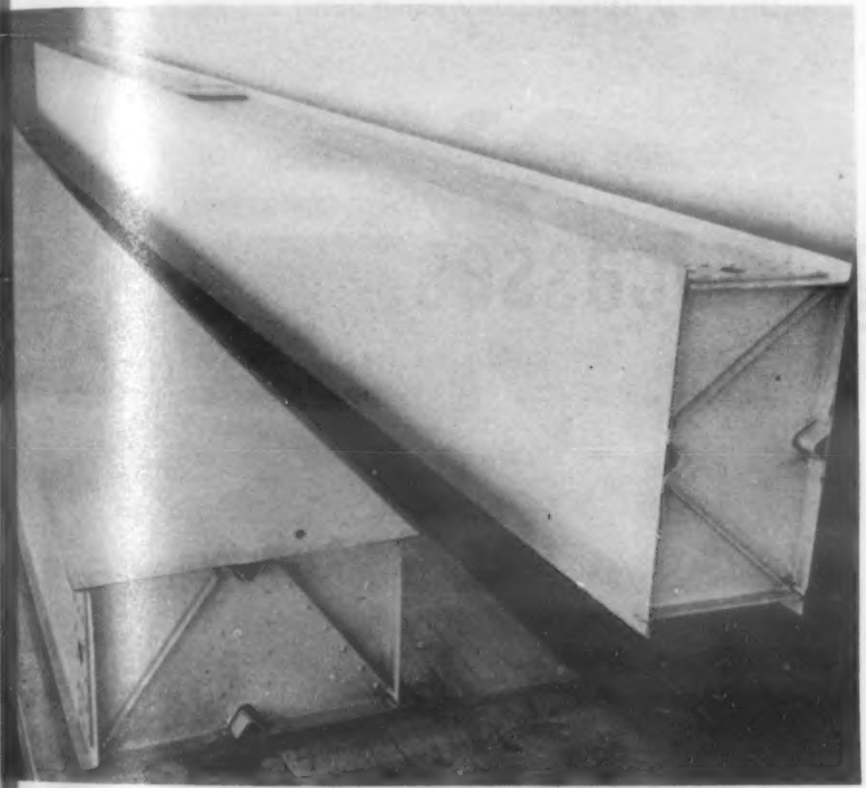
The cement requires care in handling as it will blister the human skin if left in contact with it.

Applications

Cyclewelding applications are confined largely to military aircraft at present. It is used for assembling metal wing flaps, aircraft stabilizers, bomber floors, glider ski pedestals, and many small items. Refrigerator parts, drain valves for tanks, range finder equipment, instrument mounts, and ammunition cases for tanks are also being Cyclewelded at the present time. The leading edges of wings on the Liberator bomber are cemented with Metlbond at Consolidated Vultee's plants, this type of

assembly affording greater smoothness, hence lower air resistance.

Because of its newness, adhesive bonding has in most present uses been adapted to parts already designed for riveted or welded fabrication. This has prevented full exploitation of its possibilities. An outstanding exception is the British Mosquito bomber, designed as a wooden airplane of "sandwich" materials. Inner and outer veneers in the skin are separated by a layer of balsa wood, and assembled by adhesive bonding. Such a material is extremely light, since the balsa wood has a specific gravity of about 0.2, but quite strong, the separation of the wood veneers by the balsa giving a high section modulus to the composite. The result is similar to the load-carrying ability of an I-beam, in which the web serves principally to maintain the spacing and relative positions of the flanges. The stiffness of this composite, as compared to a thin aluminum alloy skin, greatly decreases "fluttering" propensities, and so requires less bracing.



The finished assembly. Only a few rivets are used. Courtesy: Chrysler Corp.

Metal-Nonmetal Design Combinations

Advantage can be taken of these facts in metal construction also, and it is here that adhesive bonding will probably have its greatest field. Structural columns have been made in pipe form, with inner and outer surfaces of thin aluminum sheet, and balsa wood occupying the space between. The result is a member unbelievably strong in proportion to its weight. Similar design-strengthened materials have been prepared in sheet form. Metal-faced plywood has already gone into railway car construction in a limited way.

A flooring made with top and bottom sheets of ¼-in. plywood and corrugated steel sheet between again exemplifies this composite material trend. While possessing great stiffness, it weighs far less than a solid flooring of equal strength.

While the first plastics, as materials, are quite old, the plastics industry, as an industry, is comparatively young. It has produced many new materials having remarkable combinations of properties under the stimulus of war. Many of their most familiar outlets in the past have been in the production of domestic gadgets, but engineers in the immediate post-war future will start to consider them as engineering materials of construction. Adhesive bonding will certainly be called upon in the fabrication of composites in which plastics will be one of the components. Plastic-faced panels have already been mentioned for the building trades, and should prefabricated housing become the industry its proponents predict, we may expect to find many of these light weight, high strength composites in use.

The field opened to the engineer and the industrial designer by adhesive bonding is broad indeed. He may design for strength and wear resistance with metals, combine them with wood for lightness, or use plastics for beauty, glass for corrosion resistance and appearance, rubber for waterproofness or vibration insulation, and so on. Adhesive bonding promises to overcome much of the former limitations of wood and other engineering materials, and may bring about a renaissance of some engineering materials which had gone into temporary eclipse.

The Future

This new joining process is not a cure-all. It has several very definite limitations to its use. First of all, as an organic material, the cement has sharply limited heat resistance. Obviously, there will be no adhesive-bonded furnaces. Again, the materials are at present expensive. Lower costs are promised when materials and markets become stabilized again. However, it will probably have its widest applications in the field of composite materials, rather than in the joining of metals, where the economical welding methods have been highly developed. For the most part, adhesive bonding is a plant process, requiring presses, pads, heating devices, and sometimes specialized dies or forms. It is, at present, a high-production technique rather than a process for field construction or repair work.

The adhesive materials tend to deteriorate in storage over a period of months. If held at temperatures in the neighborhood of 40 F., they will last for about six to nine months. At ordinary temperatures they deteriorate more rapidly.

These composites, or sandwich materials, may be expected to play a prominent part in the post-war aircraft industry. Their properties would also suggest use in pre-fabricated panels for the building trades, in pre-fabricated houses, in furniture, in automotive and railway construction, and in the production of a host of small items, such as radios, office equipment, gadgets, and so on.

We are constantly being told of a post-war world filled with dream houses, dream automobiles, dream airplanes, dream gadgets of all kinds. Adhesive bonding may help to make a few of those dreams come true.

Fig. 1. Ordnance fuse parts finished machined from S.A.E. 4140 rod stock before heat treatment and by isothermal heating procedure hardened without change in dimensions beyond manufacturing tolerance.

Salt Bath Quenching Processes

by HAROLD J. BABCOCK

Research Engineer, Ajax Electric Co., Inc. Philadelphia

THESE WAR YEARS, with their heavy demand upon our productive facilities and the need to conserve both material and manpower, have caused engineers, metallurgists and heat treaters to make use of the S-curve to a greater extent than ever before. These transformation-temperature-time or TTT curves help beyond measure to explain some of the reactions which may occur in steel when it is heat treated. Such reactions, suitably controlled, can be applied to produce remarkable savings in man-hours, furnace hours and material. It has been chiefly in the laboratory that such control has been demonstrated. Industry has had need of a high temperature salt bath quench that is designed to control these reactions under production conditions.

It is well known that hardening steel where a severe quench is required produces distortion and even cracks in the pieces if the sections or shapes are irregular. This condition is due, in part at least, to the rate of formation of martensite. When martensite is formed in quenched steel, an increase in volume occurs, with the result that stresses are set up that often produce cracks in the piece. In the isothermal transformation method of hardening, the temperature differential between outside surface and inside of the piece being quenched is minimized and thus the stresses produced by the non-uniform formation of martensite may be avoided entirely.

Thus, guided by the "S" curve for a given steel, intricately shaped pieces may be hardened with almost no changes in dimensions and wholly free from quench or strain cracks. Records of heat treating U. S. Ordnance shell fuses in one plant show well over 3,000,000 parts hardened without loss of a

piece due to quench cracks or change in dimension beyond manufacturing tolerances where use is made of isothermal quenching. This experience has been duplicated on these parts in many other plants.

Quench-Cracking

Since war conditions have dictated the use of carbon steels or low alloy steels that can be hardened throughout only by the most severe quenching in normal practice the problem of quenching was answered in some measure by modifying the procedure from that of a uniform rate of cooling. It has long been the practice of experienced heat treaters to resort to "time quenching," "interrupted quenching" and "hot bath quenching," as a means to minimize quench cracks, internal stresses and distortion. But, the technique has been largely rule-of-thumb.

Fundamentally, the heat treater thus seeks to prevent a high rate of formation of brittle, untempered martensite and also to obtain its formation uniformly through the piece being quenched. In large measure the stresses set up by quenching may be attributed to the fact that martensite occupies a greater volume than does the austenite from which it is derived. If this change in volume, taking place during quenching, occurs uniformly, no unbalanced stresses will be set up in the structure. This ideal condition can only be realized in pieces so thin (in the case of plain carbon steel) that the results are of little practical interest.

In other words, a piece of steel, when quenched, cools most rapidly at the external surface and slowest at the center of its heaviest section. In this simply stated and universally recognized fact lies the whole problem of quenching steel. When carbon steel is heated above the upper critical, prior to quenching, the structure at this high temperature is described as stable austenite, i.e. carbon or carbide together with alloy metals in solution in iron. As this austenite cools it becomes unstable and transforms to structures identified with the rate of cooling. If cooling (quenching) is at the "critical rate," the austenite transforms to martensite. In the case of a eutectoid carbon steel, "this critical rate is the slowest cooling rate (measured at about 1020 deg.) at which a completely martensitic microstructure can be obtained."[2] This transformation begins when the temperature in any part of the steel falls below about 600 F. and continues, thereafter, to completion only as the temperature of the steel is lowered.

The portion of the piece being quenched that lies nearest the surface reaches this "martensitic point" before the center part and forms a hard, brittle "jacket" of unyielding martensite. As the interior of the piece cools the transformation to martensite, with the increase in volume that occurs, sets up internal stresses that often produce strains exceeding the tensile strength of the "jacket." If the piece is not of simplest geometric shape, having minimum ratio of length to diameter or thickness and of symmetrical proportions, quench cracks are almost certain to be produced.

Quenching Media and Rates

Thus where through-hardness is required, the problem of quenching becomes that of extracting the heat from the center of the mass being cooled. The rate of extraction must be at the "critical rate" for the particular steel involved.

In words familiar to the heat treating operator, the quench-and-temper method of hardening steel has used air, oils, saline brines and caustic brines as quenching fluids, with the quenching rate slowest in air and most rapid in caustic brines. The cooling rate in any of these fluids may be accelerated by manual or mechanical movement of the piece or by agitation of the quenching fluid by mechanical devices or by the use of jets of the fluid forced against the pieces being quenched. The rate of cooling may be further accelerated by lowering the temperature (refrigeration as the extreme condition).

But as the operator resorts to more drastic conditions of quenching to obtain through-hardness on steels of low hardenability or where he seeks to quench heavy section of alloy steel of high harden-

ENGINEERING ACHIEVEMENTS

Engineering achievements differ in their evolution. Some represent a strictly commercial super-effort, others the practical perfection of an extraordinarily useful process, machine or equipment, still others the trial-and-error development of a new material. The achievement hailed in this article is of a fourth variety—the practical exploitation of a theoretical concept and its application to important production problems. The concept is "isothermal transformation"—the transformation of steel at a constant elevated temperature as distinct from its transformation affected by quenching to room temperature and reheating; the practical utilization today is in such processes as "Martempering" and "Austempering," in which intricately-shaped steel parts are efficiently hardened without quench-cracking or significant distortion by heating above the critical, then quenching into a molten salt bath at a suitably-chosen intermediate temperature, and holding there for a short or a long time, depending on the properties desired. This article explains the basic principles underlying this achievement, describes the practical processes (Martempering, Austempering and Cycle Annealing) that utilize it and cites several outstanding applications of salt bath quenches to the improved heat treatment of various war products. —*The Editors*

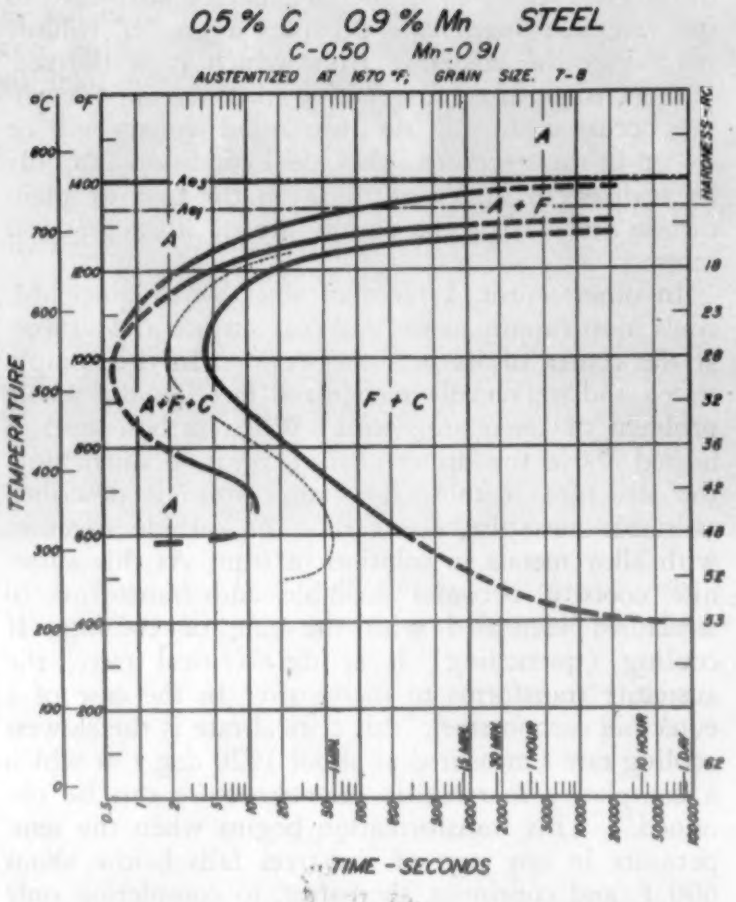


Fig. 2. TTT curve for S.A.E. 1050 steel. A plain carbon steel not high in hardenability. (U. S. Steel Corp.)

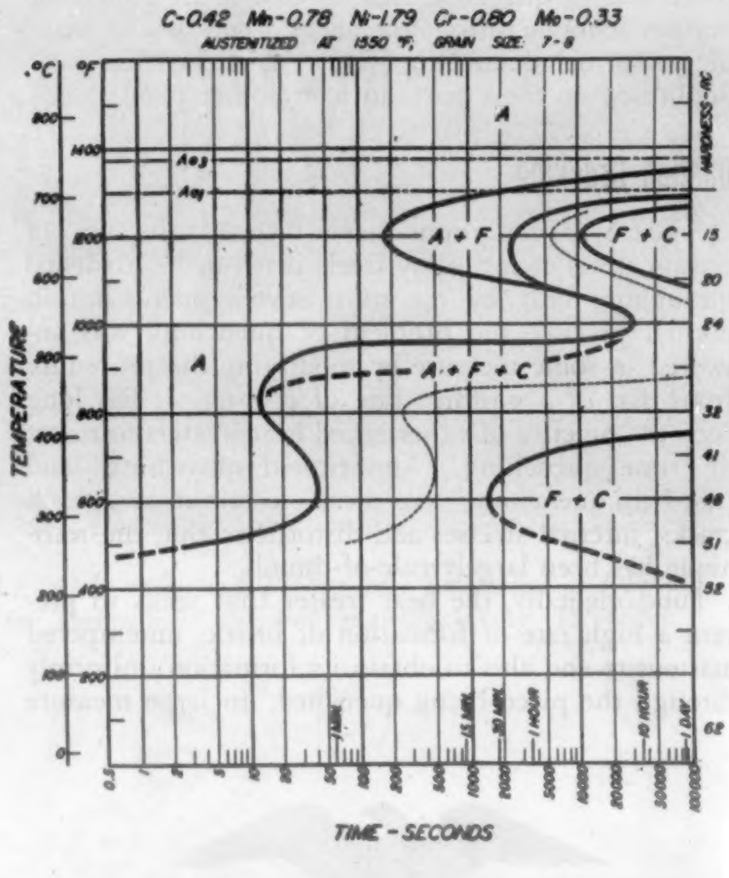


Fig. 3. TTT curve for S.A.E. 4340 steel. An alloy carbon steel of high hardenability. (U. S. Steel Corp.)

ability, he is faced with the problem of controlling the change in structure through the maximum sections he is called upon to quench. A conflict occurs. The thermal conductivity of the steel acts to hold to a constant rate the transfer of heat from the center of the hot mass being quenched to the outer surface exposed to the quenching fluid. The rate at which the quenching medium removes heat from the surface is much more rapid than that of the transfer by conduction within the piece. A serious difference in temperature between the outside and the inside results in ordinary quenching baths of high cooling power.

It is for this reason the heat treater uses that quenching medium or method which permits cooling at the required rate with the smallest temperature difference between center and outside of the piece. Experienced operators have long been using high temperature quenches (300 up to 600 F.), time quenching or interrupted quenches for this very purpose.

TTT Curves Replace Rule-of-Thumb

Up until about 1930 the heat treater resorted to such practices to control the rate of cooling within the cross section of the steel being quenched. It was a rule-of-thumb method which required a highly skilled artisan to make it work without too many failures.

Today, we are able to understand more clearly the mechanism of the changes that take place when steel is quenched. The introduction of the "S" curve or the time-temperature-transformation curves for various steels, first by the work of Edmund S. Davenport and of E. C. Bain followed by many other investigators, enables us to interpret the influence of temperature and time in terms of their effect upon the structures formed during continuous cooling of steel.

We can determine by measurement the maximum diameter rods of various steels that will harden to Rockwell C-50 at the center. The Table from A.S.M. Handbook (1939) will illustrate the results on quenching in oil and water.

Table of Results on Quenching in Oil and Water

S.A.E. No.	Grain Size	Max. diam. in In. Oil quench	Max. diam. in In. Water quench	Critical cooling rate at center, deg. F. per Sec.
1050	5-6	0.30	0.70	198
1045 plus 0.2% Cr.	6-8	0.40	0.90	134
T-1340	-	0.70	1.20	76
5140	5-8	0.92	1.55	50
3145	5-6	1.15	1.80	38
4140	6-8	1.50	2.15	29
X-3140	6-8	2.50	3.35	13
4340	-	3.40	5.00	6

In Fig. 2 and Fig. 3, we reproduce two TTT curves from the Atlas of Isothermal Transformation Diagrams,[3] published by the U. S. Steel Corp. The critical cooling rate in the last column of the Table relates directly to the TTT curves for each steel. If one

examines the curve for an S.A.E. 1050 steel in Fig. 2, it will be noted that the critical cooling rate must carry the steel to a temperature below the range of 900 to 1000 F. in not more than 0.6 seconds. Now examine the curve for an S.A.E. 4340 steel in Fig. 3. In this steel the critical cooling rate must lower the temperature below the range of 800 to 900 F. in not more than 12 sec.

It is apparent from these curves that the thickness of section that will through-harden when quenched will be in proportion to the "time gap" i.e. the space to the left of the "beginning of transformation" curve called the "nose" where it approaches most closely the vertical margin of the diagram.

This relationship between the "time gap" shown on the TTT curve of a steel and the heaviest section that can be through-hardened in a particular quench fluid is of great value. In older heat-treating practice, procedures had been worked out without the time saving help of such a guide. Thus it has come about that new practices of quenching procedure have been adopted. The "rule-of-thumb" or personal experience method has been replaced by technique based on the information disclosed by the TTT curves.

These procedures, in practical application, are illustrated by the diagrams reproduced in Figs. 4 to 7 inclusive. The cooling curve in the conventional quench and temper method as it is related to the TTT curve is shown in Fig. 4. You will note that the quench lowers the temperature of both the center and the outside of the piece of steel at such a rate that the "cooling curves" fall to the left of the "nose" of the "S" curve. The structure of the steel thus quenched is entirely martensitic.

Martempering

In Fig. 5, another method to obtain a martensitic structure is shown. This method is based upon the information now available to the heat treater in the TTT curve of each steel. The procedure has been given the name of "Martempering."[4] As defined in the article by B. F. Shepherd, "Martempering" is a term used to describe a heat-treating operation whereby martensite is produced with a minimum of residual hardening strains. The investigators working on the isothermal transformation of steel found that no martensite was formed from austenite until the steel had been cooled to certain temperatures, usually within the range of 260 to 640 F. depending on the steel being quenched.

The temperature at which martensite begins to form is designated as the Ms point. In general, it is stated that the change from austenite to martensite occurs only in proportion to the drop in temperature of the steel after it reaches the Ms point and is not an isothermal transformation. Fig. 8, presented by Morris Cohen[2], illustrates the proportional change to martensite with drop in temperature after the Ms point is passed.

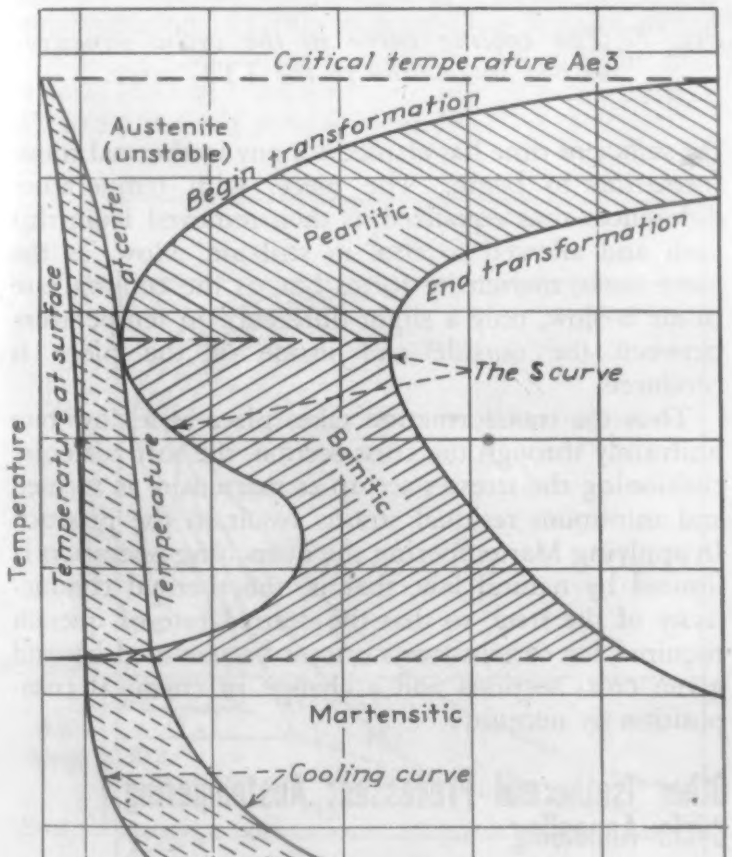


Fig. 4. The cooling curve in the quench and temper method in relation to the TTT curve.

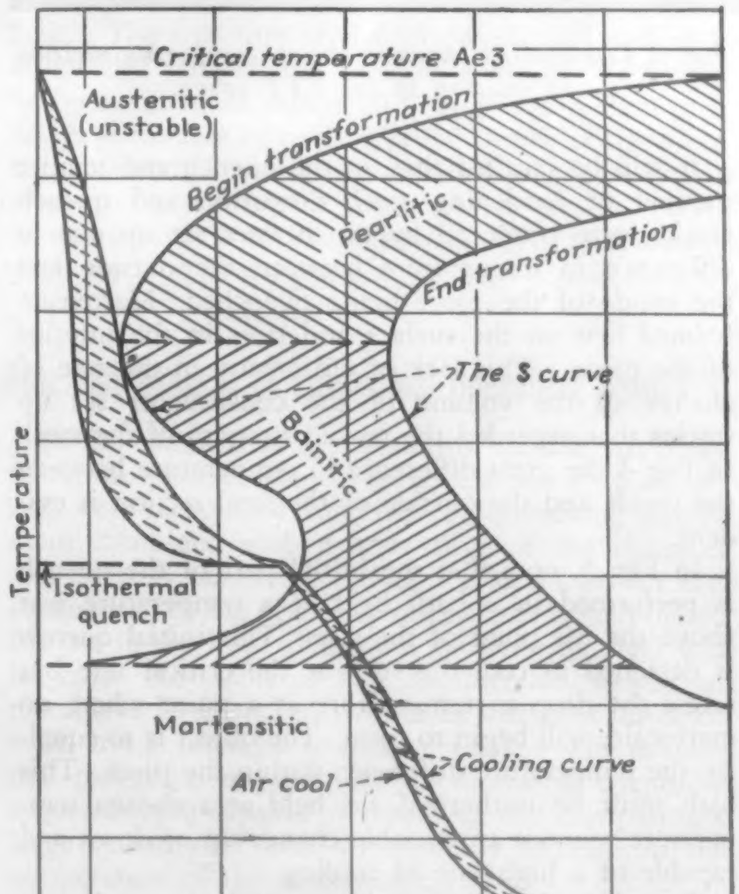


Fig. 5. The cooling curve in the martempering method in relation to the TTT curve.

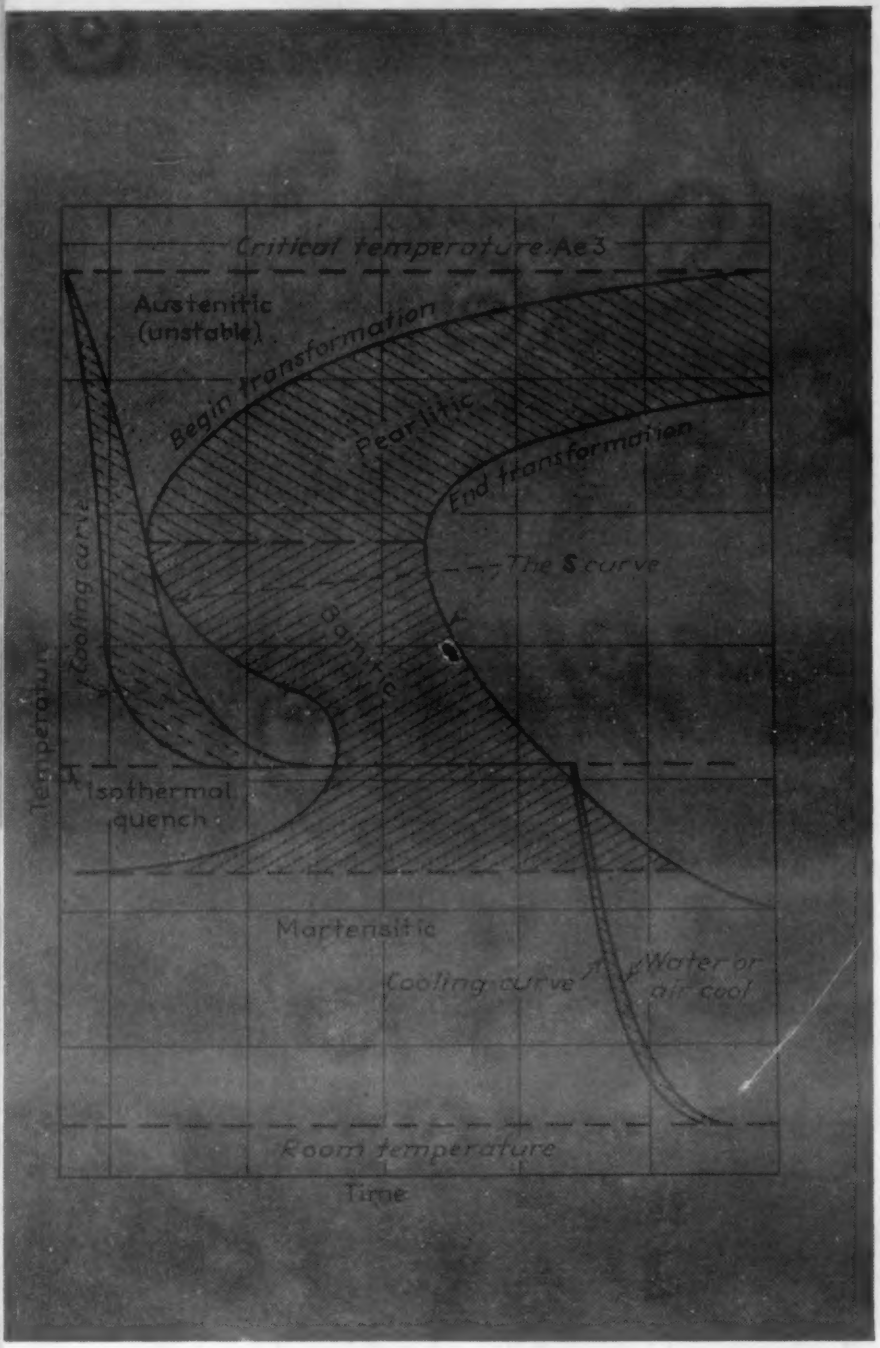


Fig. 6. The cooling curve in the austempering method in relation to the TTT curve.

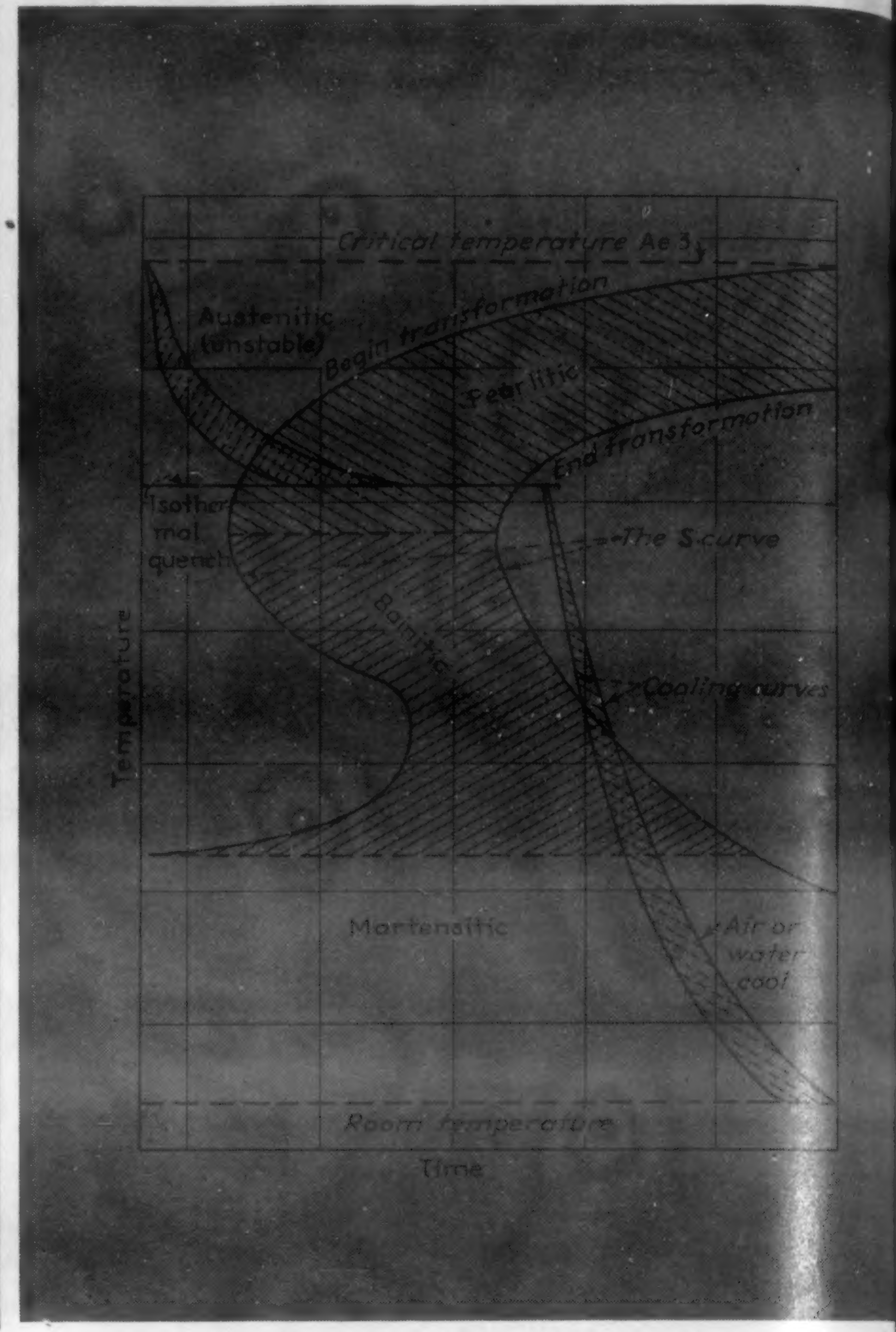


Fig. 7. The cooling curve in the cyclic annealing method in relation to the TTT curve.

It will be recalled that, in the quench and temper method of hardening steel, distortion and quench cracks were produced by the stresses set up due to difference in temperature between the outside and the inside of the piece being quenched. Martensite formed first on the surface and later in the interior of the piece. This lack of uniformity in the rate of change in the volume of the constituents set up strains that exceeded the tensile strength of the steel. In Fig. 4 the great difference in temperature between the inside and the outside of the steel section is evident.

In Fig. 5, note that the initial part of the quench is performed in a bath held at a temperature just above the Ms point of the steel. This initial quench is designed to cool the steel at the critical rate but arrest the drop in temperature at a point where no martensite will begin to form. The object is to equalize the temperature difference within the piece. This bath must be isothermal, i.e. held at a chosen temperature without appreciable change up or down and capable of a high rate of cooling.

The time the piece being quenched remains in this isothermal quench must not be long enough to pass beyond the "S" shaped line marked "Begin Transformation" or a Bainitic structure will start to form. The cooling power should be ample to stabilize the temperature difference between the inside and the outside of the heavy sections being quenched before sufficient time has elapsed for any isothermal transformation to begin. The piece, with temperature differences thus equalized, is then removed from this bath and allowed to cool in still air. Now, as the piece cools, martensite forms but, as the cooling rate in air is slow, only a slight difference in temperature between the outside and inside of the piece is produced.

Thus the transformation takes place at a slow rate uniformly through the cross section, the soft austenite cushioning the stresses set up as martensite is formed and minimum residual strains result in the product. In applying Martempering the quenching operation is limited by natural law, that is, the thermal conductivity of the steel, so that the desired rate of quench required for certain steels cannot be obtained beyond given cross sections and a change in chemical composition is necessary.

Other Isothermal Processes: Austempering, Cycle Annealing

In Fig. 6 is illustrated a method of isothermally quenching steel that is designated as Austempering. The fundamental principle of this process was first described in 1930 by E. S. Davenport and E. C. Bain[6], of the U. S. Steel Corp., and its industrial uses and possibilities comprehensively examined in 1939.[8] It produces a quenched product in which no martensitic

structure is produced at all. You will note that the initial quench is an isothermal bath held at a temperature above the Ms point of the steel. The steel remains in this bath not only long enough to equalize the temperature difference between outside and inside of the piece, but for time sufficient to permit the steel to pass through the "end of transformation" curve at the right hand boundary of the shaded area marked "Bainitic."

Then the piece may be cooled in any manner or at any rate desired (even in brine) and it is stated that no further changes in structure will occur. This bainitic structure will be found free from even microscopic quench strain cracks and the distortion due to quenching almost eliminated. It will be evident to the metallurgist that Austempering will not result in a structure having quite the hardness of martensite since a bainitic structure is in many ways equivalent to a tempered martensite.

In Fig. 7 another form of isothermal quenching is illustrated which has been described as "Cyclic Annealing." Again the information made available by this "S" or TTT curve is used to help the heat treater control better the changes in structure normally obtained by extremely slow cooling, i.e. annealing, normalizing, spheroidizing, etc. The initial quench is carried out in an isothermal bath maintained at chosen temperature above the "nose" of the curve, i.e. where a pearlitic structure is obtained.

If the piece remains in this bath for sufficient time to permit complete transformation to occur, it may be removed and cooled at any rate desired. It will not develop structures other than the soft, high temperature structure identified with the temperature of transformation. In this manner long furnace-cooled annealing cycles normally requiring 18 to 30 hr. may be completed in from 4 to 7 hr. just by using suitable salt baths at fixed temperatures.

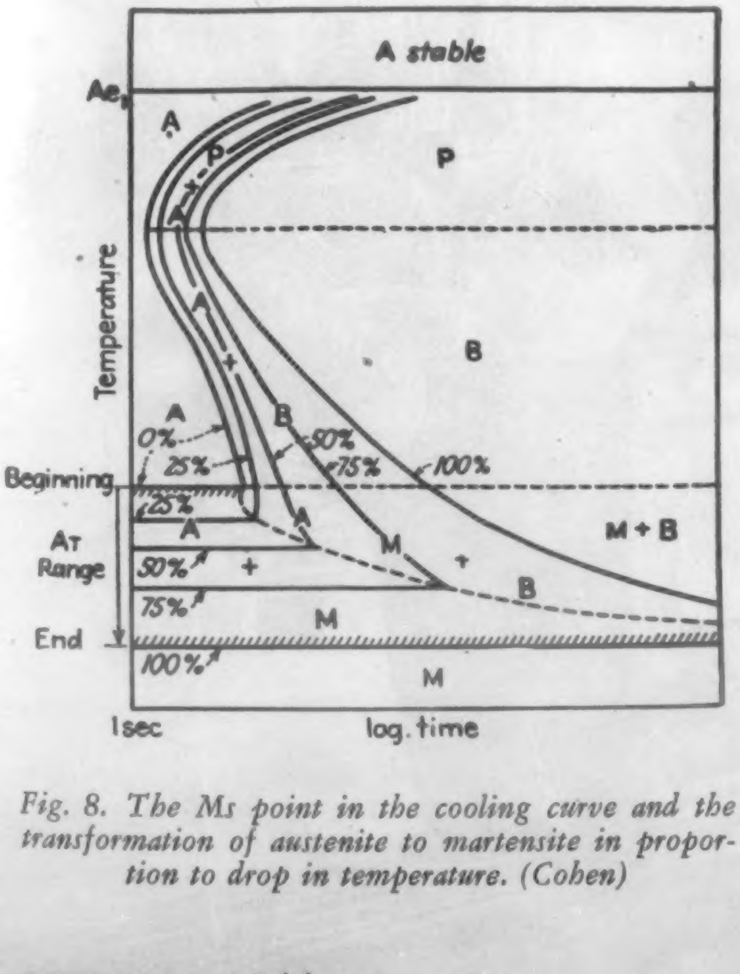


Fig. 8. The Ms point in the cooling curve and the transformation of austenite to martensite in proportion to drop in temperature. (Cohen)

Properties of Molten Salt for Quenching

Thus, briefly reviewed, we find that the information made available in the TTT curves of the various steels helps eliminate the rule-of-thumb procedure in quenching. It is obvious that the heat treater needs to familiarize himself not only with quenching into brines and oils, but also into molten salt. The greater portion of the procedures just outlined will require the use of molten salt quench baths since the baths will be maintained at temperatures above the boiling or flash points of the lower temperature fluid quenching mediums.

One property of molten salt, not widely recognized, is its cooling power at temperatures above 400 F.

A study of the cooling rates of mineral oil and of molten salt has been made by Lueg and Pomp[7]. He showed that salt at 482 F. has as great cooling power as the best quenching oil bath does at 68 F. In the mineral oils studied even at 68 F., the cooling rate is retarded because the oil first vaporizes at the hot metal surface and then boils, thus preventing the surface of the piece from coming into intimate contact with the quenching bath liquid. Obviously, at a bath temperature of 482 F. using oil is not practical.

Molten salt does not vaporize or boil even at much higher temperatures and a smooth cooling curve is the result. In the higher temperature baths molten salt is a coolant capable, at a quench bath temperature of 660 F., for example, of cooling a 0.47-in. diam. steel sphere at rates in excess of 230 F. per sec.

In using molten salt for quenching steel it must be recognized that the slope of the cooling curve is influenced greatly by a temperature rise in the quench bath. The structure of the quenched steel will vary unless this temperature remains constant. It should be borne in mind that a 10 F. rise in this bath may decrease the rate of cooling at the center of the piece being quenched sufficiently to cause that part of the curve to "pass through the nose" of the "S" curve. The result is a structure having high temperature products with lower physical properties than desired.

Practical Aspects of Isothermal Quenching Setups

In the commercial application of molten salt baths to the isothermal quench, success depends upon several well recognized functions of quenching equipment combined with a knowledge of the chemical and physical natures of the molten salts used for this procedure. The use of a conventional salt bath designed for use in the heat treat room for drawing steel will be most unsuitable if any considerable weight of metal is to be quenched. It is built with heat insulated walls and is intended to retain its heat. The isothermal procedure requires, for its successful operation, a quench bath capable of absorbing and dissipating a large quantity of heat without any increase in the temperature of the molten salt.

The isothermal quench bath must be so designed that:

1. An adequate volume (gallons per minute) of the quenching medium flows in contact with the entire surface of each piece being quenched to maintain maximum rate of cooling in terms of temperature differences involved.

Fig. 9. Isothermal high temperature salt bath quench with mechanical agitator and air cooled pot.

**Fig. 10. Typical batch type isothermal production unit for the three step salt bath process—neutral hardening, high temperature quench and draw.*

2. The quenching medium must have cooling power to extract heat from each piece throughout its maximum section at a rate at least equal to the critical rate of that steel.
3. The temperature of the quenching medium be kept constant by extracting the heat from the liquid by suitable cooling methods.

A view of such a bath having the capacity to quench 300 lb. of steel per hour is shown in Fig. 9. The only heat that need be applied in this bath is used to melt the salt when starting up the equipment or to maintain it at temperature during standby or idling periods. An automatic temperature control instrument regulates the power input to maintain the salt at the temperature set on the controls. The chief function of the bath is to extract and dissipate heat as fast as it is brought in by the steel being quenched.

Surrounding the exterior of the bath is an air chamber in which a controllable volume of air is caused to flow. Whenever the temperature of the molten salt rises more than 1 F. above the control setting, the cooling system is turned on and the bath temperature thus lowered. In order to maintain maximum quenching speed at any temperature setting a motor-driven device maintains the molten salt in violent circulation or, in some instances, a pump is used to force high pressure multi-jets of salt against the surface of the work.

The development of molten salt bath quench furnaces which are capable of dissipating the large quantity of heat brought into them from the high temperature austenizing baths without variation in temperature, marks the transfer of the isothermal transformation method from a procedure of the metallurgical laboratory to that of the commercial heat treat room.

There are many units already in commercial operation. These isothermal quench baths run in size from a small unit 14 x 9 x 12 in. up to units exceeding 12 ft. in length, 4 ft. in width and with salt depths over 6 ft. They are quenching metal in quantities varying from a few pounds to over a ton and a half an hour.

Applications to Ordnance Parts

With scores of installations placed in operation within the past year, the results obtained on a wide variety of products are most interesting. A few of the applications are outlined briefly. In the production of intricate machined parts for the U. S. Ordnance the economy in material and the reduction in costs by machining to finished dimensions before heat treatment has been thoroughly demonstrated in a large number of plants scattered all over the country.

Typical of such parts is the fuse shown in Fig. 1. As this isothermal method is applied to the heat treatment of fuse parts, the pieces are held in suitable basket type racks and, without any rehandling, are carried progressively through an electric salt bath for hardening or austenizing, the isothermal salt bath quench and the electric salt bath draw furnaces, hence onto the cooling stands, then into the wash and rinse tanks to remove the last trace of salt and from there direct to the electro-plating room.

It should be noted that by using salt baths in each of the 3 steps the total time of treatment was reduced to between 40 and 48 min. per batch compared to 1.5 to 3 hr. by the quench and temper method. Lower distortion, lower change in dimensions from heat treat and freedom from quench cracks accounted for lower production costs than with the older method of heat treatment.

In Fig. 10 one of these fuse heat treating installations is shown in operation. This unit has capacity to handle over 165,000 pairs of fuse parts per month. The plant maintains rigid government inspection and yet can look back over the production of millions of these vital war parts to find that they have yet to have a single lot rejected due to heat treatment.

The steel used in these fuse parts is W. D. 4140 and the maximum section is ½ in. in thickness. Typical of the physical properties obtained by the isothermal method on this product are the following data from an 0.505 in. tensile bar specimen:

Yield, p.s.i.	*Tensile, p.s.i.*	*Reduc. in area, %*	*Elong., %*	*Hardness, Rc*
172,000	183,000	57.7%	16.5%	35

Note that these properties combine those of a tempered martensitic steel with those of a bainitic steel structure. A detailed description of this method of treatment will be found in the paper entitled, "Isothermal Quench Baths Applied to Commercial Practice."[5] As a result of the experience with this type of fuse, there are in operation several furnaces to heat treat another type of fuse made from the same type of steel except that the maximum section to be hardened exceeds 2⅜ in. A suitable modification of the quench furnace to extract the heat from the center of this heavy section at the required rate was all that was needed in using the isothermal method.

When machine gun bolts were treated in an isothermal bath following a suitable carburizing treatment in molten salt they obtained almost complete elimination of distortion. Fig. 11 shows this combined carburizing and isothermal hardening and quench unit. The pieces, carried on racks, are immersed in a liquid carburizing bath for about 1¼ hr. to produce a suitable case, transferred to a neutral salt bath maintained just above the upper critical temperature of the case and from there directly to a molten salt quench bath at 475 F. The quench and temper method previously used required twice as long in process. With the isothermal method rehandling was reduced from over 50% of the pieces to under 2%. Distortion over 0.001 in., which would be cause for a remachining operation, was found in over 25% of the pieces by the older method, whereas the isothermal method reduced this remachining to less than 1%.

Results on Other Parts

The isothermal method of treatment has been shown to reduce stresses and to eliminate even microscopic strain cracks within the quenched structure. Steel thus treated tends to be more ductile and to possess greater impact resistance. In one well-known instance a group of bayonet knife blades were martem-

Fig. 11. A combined carburizing and isothermal hardening and quench unit. Liquid carburizing neutral hardening, isothermal quench and wash tanks in straight-line assembly.

pered and drawn to 52-55 Rc. These blades (about 3/16 in. thick) at that hardness permitted a bend test which exceeded 40 deg. without "taking a set" or breaking. The steel was W. D. 1095.

In another similar condition some S.A.E. 1095 machete blades were martempered and drawn to 56-58Rc. When the point of the blades was clamped against a 4-in. diam. steel bar, a bend test required the blade to take the form of the 4 in. mandrel with the handle and remainder of the blade pointed at the floor parallel with the point of the blade. The blade did not snap and when released was found not to have "taken a set." Thus we combine ability to "take and hold an edge," and have, at the same time, blades which will not break under severe service.

In the treatment of bearing races made from an S.A.E. 52100 steel, the isothermal quench provides a method to reduce distortion and to minimize residual strains while obtaining martensitic structures with hardness ranging from 61-63 Rc. In one case sections 1.5 in. maximum have been through-hardened with the finished pieces showing 61-62 Rc after a 300 F. treatment to temper the martensite. In another application, races of 6 to 8 in. diam. with thin section were martempered to 64-65 Rc. On test they had the desired fine grain structure, uniform distribution of carbides, with ovality and distortion under 0.003 in. and residual stress well below any values for quench and temper methods. In one plant when the rings produced by conventional methods are cut to observe extent of residual strains, the minimum the rings open up is 0.015 in. A series of runs using the isothermal method gave four lots in which the rings had zero displacement and one lot which opened up 0.008 in. when the rings were cut.

Impact resistance is appreciably increased by austempering as is amply demonstrated by the results produced on the slide for the Colt 45 automatic pistol. Extractors made from W. D. 1060 steel, hardened and drawn to 58-63 Rc by conventional oil quench methods did not have the ductility to permit a twisting test of over 90 deg. without snapping. Isothermal treatment in a two salt bath set up permitted a test twist exceeding 360 deg. Another part of the mechanism, a slide made of W. D. 1050 steel when treated by isothermal method withstood firing a minimum of 35,000 rounds and the majority exceeded 45,000 rounds before failure. Slides formerly heat treated by a complicated selective hardening procedure never withstood firing more than 5,000 rounds without failure.

The commercial application of the isothermal transformation method places particular emphasis upon the rate of cooling provided in a quench bath using molten salt. It is not intended to imply that this method will replace or supersede the conventional quench and temper procedure for all conditions. It is a procedure that enables the operator to obtain certain properties not obtainable by older methods.

The development of molten salt baths designed for use in the isothermal transformation treatment of metal parts under commercial conditions lays great emphasis upon the highly valuable information now available in the TTT curves for various steels. Such methods offer no cure-all for every heat treat problem that may plague the engineer, heat treater or metallurgist. But the isothermal quench bath offers the means to control precisely the rate of cooling and to reproduce desired quenching cycles under controllable conditions.

As engineers and metallurgists are enabled to put into commercial practice the advantages indicated by use of the TTT curves, they will abandon old practices and tend toward specification of the analysis of the steels they propose using to utilize fully the isothermal method of heat treatment.

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Specifying Engineering Steels

When ordering and selecting wrought steels for newly designed parts, there are a number of qualities that must be specified or considered so that intelligent and economical purchase or selection is possible. A list of some of these qualities and characteristics, and the way that they are expressed on standard material specifications, has been compiled. Under each item that is listed there are a number of possibilities, remarks and points to consider.

Composition

For maximum economy and quickest delivery, steels of standard composition should be used. Some of the more widely known materials standardizing agencies that issue accepted steel specifications are listed in Table 1.

Table 1

Materials Standardizing Agency	Typical Specification Designation[1]	Range of Materials Covered by This Agency
American Iron and Steel Institute	AISI C1015 NE 8620[2]	Ferrous materials (Low alloy alternate steels)
American Society for Testing Materials	ASTM A7-42	Engineering Materials
Society of Automotive Engineers	SAE 1015[3]	Materials used in the manufacture of automobiles
	AMS[4] 5060	Materials used in the manufacture of aircraft
United States Government Federal	QQ-S-671, FS No. 1015	Materials purchased by the Government
U. S. Army (War Dept.)	57-107D, Grade WD 1015	Materials purchased by the Army
U. S. Navy	46S13c	Materials purchased by the Navy

[1] *For illustrative purposes, all the specifications listed are for the same type of steel (0.15% C) except NE 8620, which is a low alloy (Cr-Ni-Mo) steel.*
[2] *NE is the prefix used to designate National Emergency Steels, a series of low alloy steels introduced by WPB.*
[3] *Since 1942 the AISI and SAE have issued a joint list of standard steels in which the SAE specification numbers correspond to the AISI designation (without the prefix) for the same steel.*
[4] *SAE Aeronautical Material Specifications.*

If the desired steel is not included in the above lists of standard materials, it should be specified by manufacturer's brand name or by analysis, giving nominal or desired percentages (and permissible variations in percentage) of important constituents.

Method of Manufacture and/or of Processing

The method of manufacture of a steel should be specified as a choice is usually possible and the manufacturing method influences the physical properties of the finished steel. In Table 2 are listed the tonnage processes for the manufacture of wrought steels.

Table 2

Manufacturing Process	Type of Steel Produced
Basic open hearth	The largest tonnage process; both carbon and alloy steels are made by this process; a moderately clean good grade of steel is produced.
Acid open hearth	Usually used only for killed[1] (carbon) steels.
Electric furnace (basic)	The most expensive process; the best quality alloy and tool steels are produced by this process.
Bessemer	The second largest tonnage process; screw stock, reinforcing bar, skelp for welded pipe, sheet bar (for tin plate and galvanized material) are made by this process.

[1] *See Table 2a. [The influence of the deoxidizing practice is important to the physical properties produced in the steel.]*

Table 2a

Type of Plain Carbon Steel	Influence of Deoxidizing Practice
Killed steel	Sufficiently deoxidized so that the steel is free from blow holes and segregations; all forging grade and, generally, all steels, above 0.25% C are killed; some structural steels (0.15-0.25% C) are also killed.
Semi-killed steel	Not so thoroughly deoxidized; structural steels (0.15-0.25% C) are either killed or semi-killed.
Rimming steel	Only partially deoxidized; clean low carbon (below 0.15% C) steel with excellent deep drawing qualities is obtained.

The form or shape in which the steel is to be purchased should be considered and specified.

The AISI classification for semi-finished steel forms is given in Table 3.

Table 3

Form	Width, In.	Thickness, In.	Cross Section, Square In.
Bloom	Width equals thickness		36 (min.)
Billet	1½ (min.)	1½ (min.)	2¼-36
Slab	10 (min.)	1½ (min.)	16 (min.)
Sheet bar	8-16	½-2	2-32

Note: Rerolling quality blooms, billets and slabs are intended for hot rolling into shapes, plates, strip, bars and wire rod.

(Continued on page 980)


FLUID WITH SOLIDS GOES IN HERE...
CUNO AUTO-KLEAN
gives you a range up to the equivalent of 170 mesh filtration ... in a compact, all-metal, permanent unit
Contaminated fluid enters filter
Flows radially through the slots between discs
Solids are held at outer edges
Filtrate rises through central channels and exits through outlet
When discs are rotated, cleaner blades comb out the solids
Thus, you keep flow on "go" with no "red lights" for cleaning.
FLUID without solids COMES OUT HERE
with NEVER A STOP FOR CLEANING HERE

Forging quality blooms, billets and slabs are intended for use in making forgings. Sheet bar is to be rolled into sheet, black plate and tin plate.

The types of finish are varied and should be specified, as they influence the physical properties as well as the selection of machining methods. Available sizes and size tolerances are also effected by the type of finish. As an example of the influence of finish on the size and size tolerances of round bars, the standard commercial finishes, sizes and tolerances are tabulated in Table 4.

Table 4a

Diameter, in In.	Cold Finished Standard Commercial Variations in Diam. in In., (minus variation only permitted)		
Carbon Steels	Mean Values of Carbon		
	0.30% or less	0.31-0.50%	over 0.50%[1]
up to 1, incl.	0.002	0.003	0.006
1 to 2, incl.	0.003	0.004	0.008
2 to 3½, incl.	0.004	0.005	0.010

[1] *This column of permissible variations also applies to bars (of all carbon contents) that have been heat treated and straightened or stress relieved.*

Various heat treatments may be given to the steel at the mill and, as these treatments profoundly effect the physical properties, the proper treatment (if any) should be explicitly specified. In the case of low carbon and some low alloy steels, no heat treatment is needed after completion of the hot rolling process. The medium alloy and medium carbon steels may be annealed after rolling; tool steels are usually sold in the annealed condition. The high carbon and alloy steels may be purchased in a normalized, spheroidized, or quenched and tempered condition, depending upon the analysis and processing. Cold drawn or cold rolled steels may be stress relieved.

Physical Properties and Characteristics

The important strength properties should be specified along with the permissible variations. One, or more, of the following is usually specified: Tensile, fatigue or impact strength, elongation and reduction in area, or a bending test.

Hardness values are commonly used criteria for machinability and for the condition of the steel. Brinell and Rockwell hardness scales are commonly used. When the hardness is expressed in BHN, a variation of 30 to 40 BHN should be allowed (±15 to ±20); if the Rockwell C scale is used, a tolerance of about ±2 points is within commercial limits (especially if the material has been heat treated).

For certain critical uses, the hardenability of a steel is specified, usually in terms of the Jominy test.

There are other characteristics such as grain size, machinability and Magnaflux, carburizing and "P-F" tests that may be included in special purpose (especially in aircraft quality) steel specifications.

Alternates and Substitutes

When ordering a given material, an alternate (a material as good, physically, as the original) and/or a substitute (something not quite as good as that specified, but temporarily acceptable) should be indicated.

In selecting and comparing steels and in choosing alternates, comparisons of physical properties (strength, elastic properties, wearability and hardenability) should be the criteria, rather than chemical analyses.

Table 4

Finish	*Diameters, in Inches*	*Standard Manufacturing Tolerances, in Inches*	*Remarks*
Hot rolled	1/8-2 (incl., by 16ths)	±0.005 to ±1/64[1]	This material has a rough scaly finish and the bars are not too straight (unless machine straightened).[2]
	2-8 (incl., by 8ths)	Standard to 1/32-3/32 oversize	
Forged	8-12 (incl., by 4ths)	½-¾ oversize	
Cold finished	1/16-3½ (incl., by 16ths)	See Table 4a	For sizes 1¼ in. and larger in diam., either cold finished or turned and polished bars are furnished at the mill's option (unless otherwise specified).
Hot rolled, turned and polished	¼-2 (incl., by 32dths)	Standard to 0.002-0.003 undersize	This type of steel is practically stress-free.
	2-8 (incl., by 16ths)	Standard to 0.004-0.006 undersize	
	8-10 (few sizes rolled)		
Hot rolled, turned, ground and polished[3]	1 1/8-2 7/16 (incl., by 16ths)	Standard to 0.002 undersize	This is a more expensive finish, and the material is generally used without machining (for shafting, etc.).
	2½-5 (incl., by 16ths)	Standard to 0.003 undersize	
	5-6 (few sizes rolled)	Standard to 0.003 undersize	

[1] *Commercial size tolerances increase with bar sizes.*
[2] *As-rolled bars should be straight within ±¼ in. in any 5 ft. of length. Machined straightened bars should be straight within ±⅛ in. any 5 ft. of length.*
[3] *"Accuracy stock," (turned, ground and polished bars) available in small sizes (⅛-1¼ incl. by 16ths) with a size tolerance of ±0.0005 in.*

Compiled by Robert S. Burpo, Jr.

METALS and ALLOYS

Engineering File Facts

NUMBER 62
October, 1944

PROCESSES AND PROCEDURES
Heat Treating

Controlled Protective Atmospheres for Steel

Attempts to control the changes occurring in steel through exposure to air at elevated temperatures have led to the use of the salt bath and the controlled atmosphere. The latter type of control is considered in this *Engineering File Facts* number.

At temperatures above 1200 F. a scale is formed on steel when air is present, the scale becoming heavier as temperatures go higher. The scaling of steel is due to oxidation of the metal surface. Principal scaling or oxidizing gases in the ordinary products of combustion are oxygen, water vapor, and carbon dioxide. Reducing constituents are carbon monoxide, unburned hydrocarbons, such as methane, and hydrogen. Sulphur dioxide from the combustion of sulphur present in most fuels also tends to cause scaling. Nitrogen in molecular form is neutral.

The effect of various constituents of furnace atmospheres upon those of steel may be tabulated as follows:

	CO_2	CO	CH_4	O_2	H_2O	H_2
Iron carbide	oxidizing, decarburizing			oxidizing, decarburizing	oxidizing, decarburizing	decarburizing
Pure iron	oxidizing	carburizing	carburizing	oxidizing	oxidizing	
Iron oxide		reducing	reducing			reducing

With the open-fired furnace, atmosphere control is largely limited to attempting to control the products of combustion by regulating fuel-air ratios. An atmosphere of this sort cannot be made completely neutral, *i.e.,* neither scale-forming nor decarburizing, since water vapor, and usually some carbon dioxide, would always be present.

Types of Atmospheres

Specially prepared atmospheres, used in full-muffle fuel-fired or electric furnaces, can be grouped into the following classifications:

Partially burned fuel gas, (city gas, natural gas, petroleum gas, etc.) partially dehydrated. The most common of all the prepared atmospheres. Used for bright or clean annealing of low carbon steel, or, if exposure be less than 30 min., for bright or clean annealing of medium carbon steel.

Completely burned fuel gas. For tempering or drawing of steels where exposure is short and temperatures low (under 1200 F.). Partial dehydration necessary.

Completely burned, scrubbed, fuel gas. The dehydrated gas is scrubbed to remove carbon dioxide and water vapor. This treatment makes it a suitable atmosphere for the higher-temperature protection of the high-carbon and alloy steels, as in the prolonged exposure of these steels at temperatures to 1600 F. in bright annealing. Shorter exposures to 2000 F., as in bright normalizing, are safe.

Partially reacted (cracked) fuel gas. Heat must be applied, and a catalyst is used to promote the reaction. Partially dehydrated. Suitable for bright annealing of low carbon steels requiring long exposures at temperatures to 1400 F., or for bright or clean tempering of low or medium carbon steels for shorter exposures at temperatures to 1200 F. May be used with low carbon steels, in bright or clean normalizing operations to 1800 F. if time of exposure is short (under 2 hr.). By reducing the proportion of air and increasing the temperature of reaction, the composition of the atmosphere can be varied so that it becomes suitable for bright annealing or clean hardening high carbon steels.

Partially reacted, scrubbed, fuel gas. Scrubbing the atmospheric gas obtained above, to remove carbon dioxide and water vapor, permits its use with high carbon steels in temperature ranges of 1600 to 2000 F., depending upon time of exposure.

Completely reacted fuel gas. The reaction occurs at high temperature, in contact with a catalyst. Treatment with a drying agent further to reduce water vapor content usually follows cooling and condensing out of moisture. May be used for bright hardening of medium or high carbon, high-speed, or alloy steels without decarburization at temperatures to 2400 F. if exposure be short.

Dissociated ammonia. Anhydrous ammonia is broken down to hydrogen and nitrogen by passing the gas through an electrically heated dissociator. A drying tower may be required prior to dissociation when water vapor is present in the gas. Adjustment to a required temperature range and to a particular steel may be obtained by adding natural gas or other hydrocarbon to the atmosphere. This atmosphere finds its chief use in the bright annealing of stainless steel.

Partially burned dissociated ammonia. By burning part of the hydrogen and chilling to condense out the resulting water vapor, an atmosphere higher in nitrogen may be produced.

Completely burned dissociated ammonia. After drying, this gas is essentially pure nitrogen. It is one of the most expensive of the prepared atmospheres, and its most common use is in the annealing of stainless steel. The chief disadvantage of all inert atmospheres is that, in the event of air leakage into the furnace, there is nothing to prevent the oxygen from attacking the work.

Charcoal gas. Made by passing air over hot charcoal. Operating temperatures may be from 1800 F. to 2300 F., the lower temperature permitting some carbon dioxide formation, the higher holding carbon dioxide below 1%. The gas is suitable for annealing low-carbon steel or other treatments not involving higher temperature ranges, but can be used for bright annealing or clean hardening medium- and high-carbon steels if carbon dioxide be absent. Carbon dioxide, when present, can be removed by scrubbing.

Charcoal gas with additives. By adding small amounts of anhydrous ammonia and a quantity of a hydrocarbon, as benzol, sufficient to counteract the carbon dioxide, charcoal gas can be used with higher-carbon steels. Ammonia increases the hydrogen content, while the quantity of hydrocarbon can be varied to neutralize out the decarburizing effects with respect to high-carbon or tool steels.

Partly burned fuel gas with internal purge. Lithium vaporized in the stream of atmospheric gas into the furnace reacts with carbon dioxide, oxygen, and water vapor, to remove these constituents in the furnace.

Hydrogen, pure or mixed. Hydrogen, carefully dried, is used in some heat treating applications, especially the bright tempering of high grade steels and in metal or carbide sintering. It may be obtained by the electrolytic dissociation of water, or purchased as bottled compressed gas, or, mixed with nitrogen, from the dissociation of ammonia, or by reaction of steam and iron.

Selecting an Atmosphere

In the selection of an atmosphere for any particular application, three factors must be considered: (1) The temperature of the furnace. An atmosphere that will be non-reactive at 1200 F. may cause discoloration, etc. at 1500 F., while at temperatures above 2000 F., even small amounts of water vapor, carbon dioxide, etc. exert a considerable effect. (2) The carbon content of the steel. Since the carbon content of the steel at its surface tends toward an equilibrium with the carburizing-decarburizing constituents of the atmosphere, the higher-carbon steels are more subject to decarburization or "soft skin" and the lower-carbon steels to carburization or "eggshell case." (3) The length of time of exposure.

Atmospheres intended for heat treating operations requiring 30 min. need not be as critically regulated as those for cycles of several hours.

(Continued on page 985)


N·B·M SILVER BABBITT STANDS UP
UNDER HIGH SPEED—HEAVY LOAD
SILVER BABBITT NO. 397
NATIONAL BEARING METALS CORP.
ST. LOUIS, MO.
N·B·M

NUMBER 62 (Continued) — CONTROLLED PROTECTIVE ATMOSPHERES FOR STEEL

Compositions of Some Typical Atmospheres

	O_2	CO	CO_2	N_2	H_2	CH_4
Partially bound fuel gas	0	1.5	10.5	86.0	1.2	0.0
Completely burned fuel gas	0	0.5	10.0	89.0	0.5	0.0
Completely burned, scrubbed fuel gas	0	3.0	0.0	94.0	3.0	0.0
Partially reacted fuel gas	0	10.0	5.0	69.0	15.0	1.0
Partially reacted, scrubbed fuel gas	0	11.0	0.0	72.0	16.0	1.0
Completely reacted fuel gas	0	19.0	0.0	41.7	38.0	1.3
Dissociated ammonia	0	0.0	0.0	25.0	75.0	0.0
Partially burned dissociated ammonia	0	0.0	0.0	80.0	20.0	0.0
Completely burned dissociated ammonia	0	0.0	0.0	99.0	1.0	0.0
Charcoal gas (produced at 1800 F.)	0	25.0	3.0	69.0	3.0	0.0
Charcoal gas (produced at 2300 F.)	0	34.7	0.0	64.1	1.2	0.0
Charcoal gas with additives	0	29.5	2.5	55.5	12.5	1.0

Note: These compositions are approximate only, may vary in the equipment of different suppliers, with the type of fuel used, and with the adjustment of the equipment controls.

As has been stated, carbon dioxide, water vapor, etc., are decarburizing to steel. Upon the other hand, methane, benzol, and other hydrocarbons are carburizing. If the carburizing and decarburizing, oxidizing and reducing effects of the various constituents could be brought into equilibrium, it would not be necessary, theoretically, to remove anything in order to have an inert atmosphere. Unfortunately, it is not possible to do this, but it has been found that additions of small quantities of carburizing gases will bring into equilibrium decarburizing tendencies of atmosphere constituents. An indication of how these equilibriums are affected by temperature is given by the curves prepared by N. R. Stansel—"Industrial Electric Heating," J. Wiley & Sons, 1933.

Recent studies of equilibrium between the carbon pressures of the steel and of the surrounding atmosphere are making possible more accurate control of carburizing-decarburizing tendencies than formerly.

One of the most generally used procedures in preparing an atmosphere is dehydration. The most common method of lowering the water vapor content of the gases is a preliminary cooling to about 40 F., in which water is condensed out, leaving a residual of less than 1%. When further reduction of water vapor content is required, a refrigeration to low temperature may be used, or, more frequently, a chemical dehydrating agent, such as activated alumina, may be employed. Carbon dioxide may be removed by absorption in caustic or ethanolamine, or by a cracking process in which it is forced to react with hydrogen, and the resulting water vapor removed. Oxygen is, of course, removed in the original burning, the air-fuel ratio control determining what the products of combustion will be.

Carbon monoxide must usually be eliminated from atmospheres intended for treating high-chromium or stainless steels, as it has a slight oxidizing effect upon chromium. Carefully dried dissociated ammonia is commonly used for bright annealing the stainless steels.

When hydrogen is used as an atmosphere, it must usually be dried. Absorption of moisture by phosphorus pentachloride gives extreme dryness, corresponding to a dewpoint of —100 to —140 F. Activated alumina is also used as a drying agent with hydrogen.

Type of Steel	Treatment	Approx. Temp., F.	Time Required	Types of Atmospheres Most Used
Low Carbon	Bright anneal	1200-1400	Few min. to several hr.	Partially burned, partially burned and scrubbed, fuel gases.
	Cu brazing	2050	To 30 min.	Same as above.
Medium Carbon	Bright anneal	1200-1500	To 30 min.	Partially burned and scrubbed fuel gas.
			Over 2 hr.	Completely burned and scrubbed fuel gas, partially burned and scrubbed fuel gas, partially reacted fuel gas, completely reacted fuel gas, charcoal gas, charcoal gas with additives.
	Clean hardening	1400-1600	Under 2 hr.	Completely reacted partially or completely burned and scrubbed fuel gas, charcoal gas, charcoal gas with additives.
	Cu brazing	2050	Under 2 hr.	Partially burned and scrubbed fuel gas, completely reacted fuel gas, charcoal gas, charcoal gas with additives.
	Tempering	to 1000	Under 2 hr.	Partially burned fuel gas, completely burned and scrubbed fuel gas.
High Carbon	Bright anneal	1200-1500	Under 2 hr.	Partially or completely burned and scrubbed fuel gas, partially or completely reacted fuel gas, charcoal gas, charcoal gas with additives.
			Over 2 hr.	Completely burned and scrubbed fuel gas, partially or completely reacted fuel gas, charcoal gas (high temp. reacted), charcoal gas with additives.
	Clean hardening	1400-1800	Under 2 hr.	Partially or completely burned and scrubbed fuel gas, partially or completely reacted fuel gas, charcoal gas, charcoal gas with additives.
	Cu brazing	2050		Partially burned and scrubbed fuel gas, completely reacted fuel gas, charcoal gas, charcoal gas with additives.
	Tempering	to 1200	Under 2 hr.	Completely burned and scrubbed or partially burned fuel gas; hydrogen, pure or mixed.
Tool Steels, Alloy Steels	Anneal	1300-1600	Over 2 hr.	Completely burned and scrubbed fuel gas, partially burned and scrubbed fuel gas, dissociated ammonia.
	Clean hardening	1400-2400	Under 2 hr.	Partially or completely burned and scrubbed fuel gas, completely reacted fuel gas, dissociated ammonia.
	Tempering	to 1200	Under 2 hr.	Completely burned and scrubbed or partially burned fuel gas; hydrogen, pure or mixed.
Stainless Steels	Bright anneal	1800-2100	Over 2 hr.	Hydrogen, pure or mixed; dissociated ammonia.
Metal Powders	Sintering	Varies widely		Partially or completely reacted fuel gas; hydrogen pure or mixed.

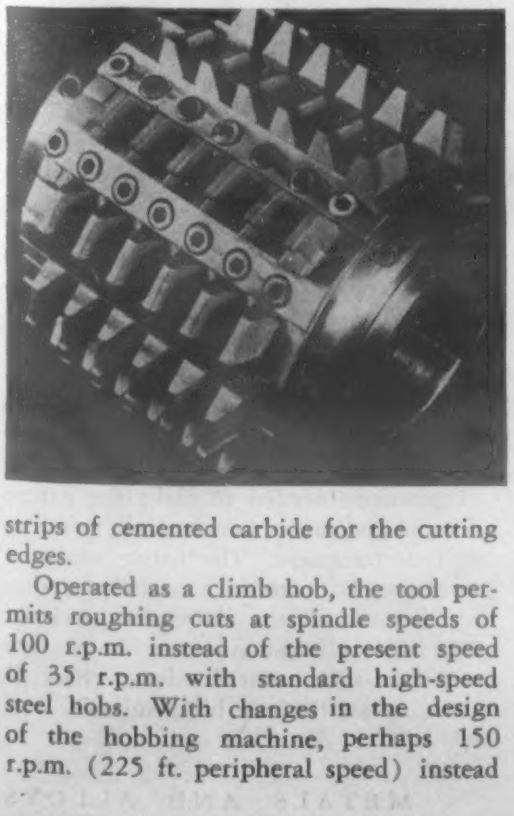
Prepared by Kenneth Rose, Engineering Editor

METALLURGICAL ENGINEERING shop notes

New Method for Gear Cutting

by Capt. E. D. Almy,
Joshua Hendy Iron Works

The use of a new composite hob in the construction of marine steam propulsion units, which broke a bad bottleneck, may result in important changes of design and method affecting the whole gear-cutting industry. The composite hob consists of a hob body and mechanically held



strips of cemented carbide for the cutting edges.

Operated as a climb hob, the tool permits roughing cuts at spindle speeds of 100 r.p.m. instead of the present speed of 35 r.p.m. with standard high-speed steel hobs. With changes in the design of the hobbing machine, perhaps 150 r.p.m. (225 ft. peripheral speed) instead of the present norm of 45 ft. peripheral at 40 r.p.m. may be possible.

Gears thus hobbed reveal an exceptionally fine finish and exceptionally accurate helix angles, which Navy engineers attribute to a combination of the clean cutting action of the carbide with climb hobbing.

For the Navy's experimentation, the Cleveland Hobbing Machine Co. built two hobs, 6 in. diam. and 2½ in. bore. They were 5-pitch, single thread hobs with strip teeth, the left-hand one having teeth tipped with cemented carbide, the right, 18-4-2 high-speed steel.

Experiments were conducted at the Joshua Hendy Iron Works, Sunnyvale, Calif. Initial tests were made on softer metal, low carbon pinion blanks having been mounted on the 72-in. hobbing machine.

First, the right hand hob with the 18-4-2 teeth was used with the prepared blank, feed up, rotation down, climb hobbing at normal 35 r.p.m. and 0.045 feed; then the left-hand hob with carbide tips was adjusted and tested at speeds up to 100 r.p.m. wth 0.045 feed, also climb hobbing. Operations were then repeated on the blank regularly used for the pinions of 8500 h.p. C-3 marine turbines.

The carbide-tipped hob, at the end of the operation, was found in much better condition than standard hobs for the same operation. It was suggested that a new hob might be brought out with four convolutions added to the present length, the first two or three tapered.

A study will be made at Joshua Hendy to see what changes can be made on existing machines to adapt them to higher spindle speeds. With the composite hob, a broken tooth means merely replacement of one tooth strip. Moreover, hardening and heat treating are easier with tooth strips alone than an entire hob. By this method, time for cutting marine gears may be reduced by 66% or more.

In the accompanying photo is the new composite 5-pitch, single-thread hob, with strip teeth tipped with cemented carbide. It has 11 rows of six teeth each, 6 in. diam. and 2½-in. bore.

Rotors of certain types of motors were previously equipped with banding rings of either copper or brass, solely so that the rotor could be balanced dynamically by applying drops of solder to the band as required, as solder would adhere easily and tightly to either metal. To conserve copper and brass, the bands are now made with lead-coated steel. Because of the greater tensile strength of the steel, the weight of the band has been reduced by nearly 60% since a thinner band can be used—and a thinner band leaves a greater radial space for the balancing solder.

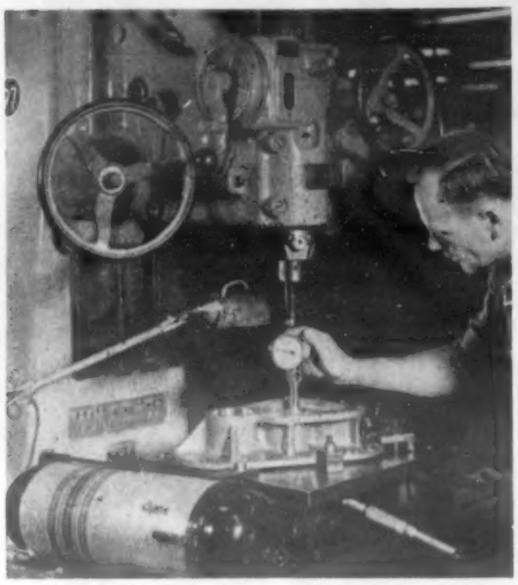
—General Electric Co.

Removing Chips By Vacuum Cleaner

by Thomas Harris,
Apex Electrical Mfg. Co.

There are many devices for getting chips out of the way in a machining operation. Too many of the ideas result in blowing the chips away with an air hose—but into some other unwanted location.

Thus, at the Apex Electrical Mfg. Co., Cleveland, where Pratt & Whitney jig



borers were being operated in turning out precision-made aircraft parts, workmen found it difficult to make accurate measurements because of surplus chip dust.

Finally, they drafted into service another of their own products, an Apex vacuum tank cleaner. Now the operator presses a button and the chips, dust and dirt are sucked into the vacuum cleaner—out of the way at once and for all. Previously, air hoses blew the impedimenta into the jig borers, clogging them and making measurements difficult.

So successful were the vacuum cleaners that they were installed elsewhere. Overall work improvement, as a result, amounted to 8% during a three-month trial period.

It's true! A welder sent in a use for low temperature welding that even our research department had overlooked. He welded a broken human tooth!

—"Eutectic Welder"
Eutectic Welding Alloys, Inc.

Homemade Tractor

by Ervy Nichols,
Missouri Valley Bridge & Iron Co.

One of the most useful machines around our shipyard is a homemade tractor that was made in our welding school from salvaged material. With it we load trucks, rack steel, move arc welders and many things that motor cranes were called for. It can pick up and tote any load up to 2000 lb. It has taken the place of a motor crane, and has saved 60% in time in our part of the yard.

We had no plans or blueprints—we just started building and wound up with a tractor 10 ft. long and 41 in. wide. It was built in our shop from scrap flanged beams and small plates. The scrap steel was cut by acetylene torch and arc welded together. Everything was fabricated by our employees except the motor, two front wheels and transmission.

The machine is powered by a 3 h.p. Wisconsin gasoline engine, with a centrifugal clutch. It is reduced down with five V-type pulleys from engine to transmission, a 32 to 1 ratio. The power hoist is built of V-type pulleys off of the transmission up to the friction clutch.

The main hoisting drum is driven by used fly wheels, with the starting gear from a Chevrolet truck. The main drum has safety dogs to hold the load.

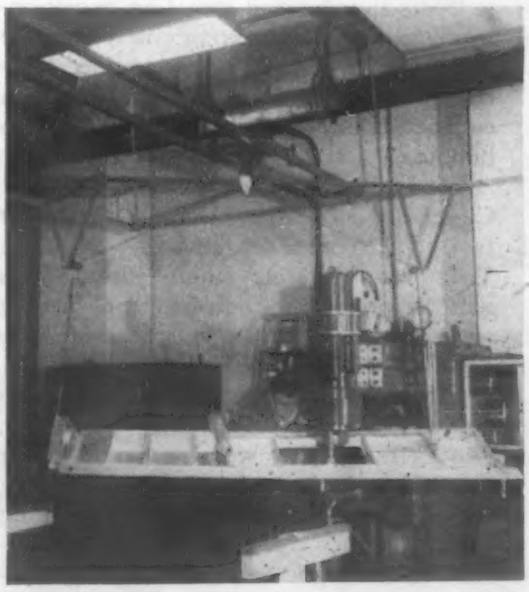
The rear wheels are of steel, 37½ in. in diam., which are ribbed for traction; the front wheels, 20 in. in diam., are of solid rubber.

Work Support Aids Spot Welding

by W. H. Ray,
Glenn L. Martin Co.

An overhead support, similar in construction to a small crane, has solved one of the main limitations of spot welding at the Glenn L. Martin Co., Baltimore. Traveling on small rollers on an overhead track, the support can be moved almost effortlessly in any lateral direction.

It is extremely simple—a horizontal beam that pivots from a supporting trolley on a pin that permits 360° rotation. The assembly to be spot welded is suspended from this beam by springs attached by



quick acting clamps, and is counterbalanced for easy handling.

The device has permitted redesign from riveting of parts, such as bomb bay and wheel well doors, formerly considered impractical for spot welding due to their size and weight, to take advantage of the more highly productive spot weld equipment.

Portable Gratings for Heat Treating

by Arthur L. Greene,
Irving Subway Grating Co.

Parts for vital war machinery were formerly loaded onto fixed grates in the furnaces of the New England Metallurgical Corp. to be treated at 1050 F. It was a tiresome and time-wasting process.

At length, officials of the New England company conferred with those of Irving

Subway Grating Co. and devised removable steel trays of grating, 36 in. sq. These gratings are loaded outside and shoved into the furnace. While one batch of small parts is being treated, another is being made ready for the furnace.

We rigged up a blower to fan the ends of blooms in the aluminum extrusion operation. This definitely increases the ease of handling, saves time as the bloom cools much faster and permits handling even without gloves.

—William R. Brasile,
Vernon Works, Aluminum Co. of America

Fixture for Jominy Tests

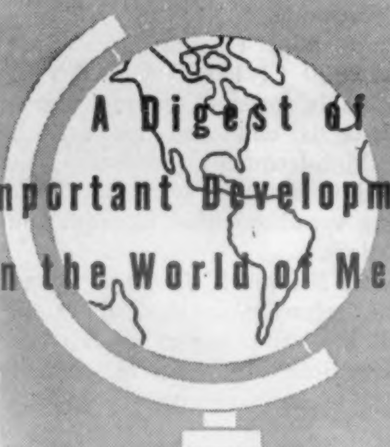
by R. E. Christin,
Columbus Bolt Works Co.

Jominy hardenability tests are run in our plant to further our check on material received from the mills. We built a fixture that obtains with speed and accuracy 1/16-in. increments on Jominy hardenability samples. This fixture sets in the screw recess of the Rockwell machine. One complete revolution of the thumb screw is equivalent to 1/16 in.

The cost of this fixture, labor and material is about $90, well worth the price where the amount of testing is considerable.

Operations needed to make the fixture are lathe and layout bench work, grinding and heat treatment. The fixture must, of course, be made to fit accurately so that it will mark off the sixteenths precisely, as a Rockwell machine can be a very unreliable source for hardness check if conditions are the least bit unsuitable.

Metallurgical Engineering Digest



1 Metal Production

Blast Furnace Practice, Smelting, Direct Reduction and Electrorefining. Open-Hearth, Bessemer, Electric Furnace Melting Practice, Equipment and Refractories. Melting and Manufacture of Non-Ferrous Metals and Alloys. Soaking Pits and Other Steel-Mill and Non-Ferrous Mill Heating Furnaces. Steel and Non-Ferrous Rolling, Wire Mill, Pickling and Heavy Forging Practice.

2 Foundry Practice

Melting and Pouring of Gray Iron, Malleable, Steel, Brass and Bronze, Aluminum and Magnesium Castings. Molding, Core-Making, Gating and Risering, etc. Foundry Furnaces, Refractories, Ovens, Molds, Sands, Binders, Auxiliary Equipment and Materials.

3 Metal-Working and Treating

Die Casting. Powder Metallurgy. Drop, Hammer and Upset Forging. Press-Forming, Drawing, Extruding and Stamping. Machining, Grinding and Polishing. Hardening, Tempering, Age-Hardening, Annealing and Malleableizing, Carburizing, Nitriding and Surface Hardening. Heating Furnaces, Refractories, Fuels and Auxiliaries. Welding, Flame-Cutting, Hardfacing, Brazing, Soldering and Riveting. Cleaning, Pickling, Degreasing and Sandblasting, Electroplating, Anodizing, Galvanizing, Metal-Spraying, Coloring, Buffing and Organic Finishing.

4 Materials and Engineering Design

Engineering Properties of Metals and Alloys. Resistance to Corrosion, Wear, Fatigue, Creep, etc. Engineering Design Problems of Specific Industries and Products. Selection of Metals, Metal-Forms and Fabricating Methods. Non-Metallics in the Metal Industries. Applications of Individual Materials. Conservation and Substitution.

5 Testing, Inspection and Control

Specifications. Physical and Mechanical Property Testing and Inspection. Routine Control and Instrumentation. Radiography and Magnetic Inspection, Spectrographic and Photoelastic Analysis. Corrosion- and Wear-Testing. Examination of Coatings. Surface Measurements. Metallographic Inspection and Technique.

1 Metal Production

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CONTENTS

Pure Oxide Refractories

Condensed from "Metallurgia"

With the possible exception of a few substances, such as nitrides of boron or magnesium, refractories for temperatures above 1700 C. (3100 F.) are limited to refractory oxides, such as alumina, magnesia, lime, beryllia, thoria, ceria, yttria, zirconia, or compounds such as spinels, or zircon.

Lime is comparatively unstable in the presence of water and carbon dioxide. The oxides possess little or no plasticity, and preparation of ware presents considerable difficulties.

In general, they show mechanical strength, physical stability, comparative chemical inertness, and electrical resistivity. Bricks, tubes, muffles, boats and other containers are used in precious metal-melting, ceramics, radio, and powder metallurgy. Thermocouple insulators and sheaths, pyrometers, miscellaneous furnace tubes, and laboratory equipment make use of these oxides.

Fused alumina, in a 99.8% pure grade, is available in thin-walled ware down to 1/16 in. thickness. It is usable to 1950 C. (3540 F.). Molded, cast or machine-made shapes are used for lining high-temperature electric or gas-fired furnaces. Recrystallized alumina of 99.98% purity is impermeable, hence suitable for heating in vacuum or in operations where contamination must be avoided.

Beryllia has been generally available only during the past 10 years, while the 99.8% pure material has been marketed only during the past seven years. It is usable to 2400 C. (4350 F.), and possesses good chemical stability, but forms fusible slags with alumina, magnesia, etc., at high temperatures. It is less sensitive than alumina to sharp temperature changes, has higher thermal conductivity and higher electrical resistivity. Beryllia crucibles have been used for melting pure beryllium and pure platinum.

While pure magnesia does not melt below 2800 C. (5070 F.), this figure is considerably lowered by impurities. Fused magnesia is employed for miscellaneous basic high-frequency induction elements, etc., while sintered magnesia is used in melting vanadium, molybdenum and tungsten alloys.

Thoria has the highest melting point of all the refractory oxides, about 3000 C. (5430 F.). It possesses a high coefficient of expansion, high density, and high resistence to basic compounds at high temperatures. Successful melting of platinum and iridium in thoria crucibles has been claimed.

Zirconia ware may be used to 2500 C. (4530 F.). When pure, it is especially sensitive to temperature changes, but the addition of small quantities of other oxides reduces this defect without greatly lowering the refractoriness. Crucibles have been used for melting pure chromium and platinum, and the material is receiving increasing attention for use in electric induction furnaces.

—D. Kirby. *Metallurgia,* Vol. 30, June 1944, pp. 65-69.

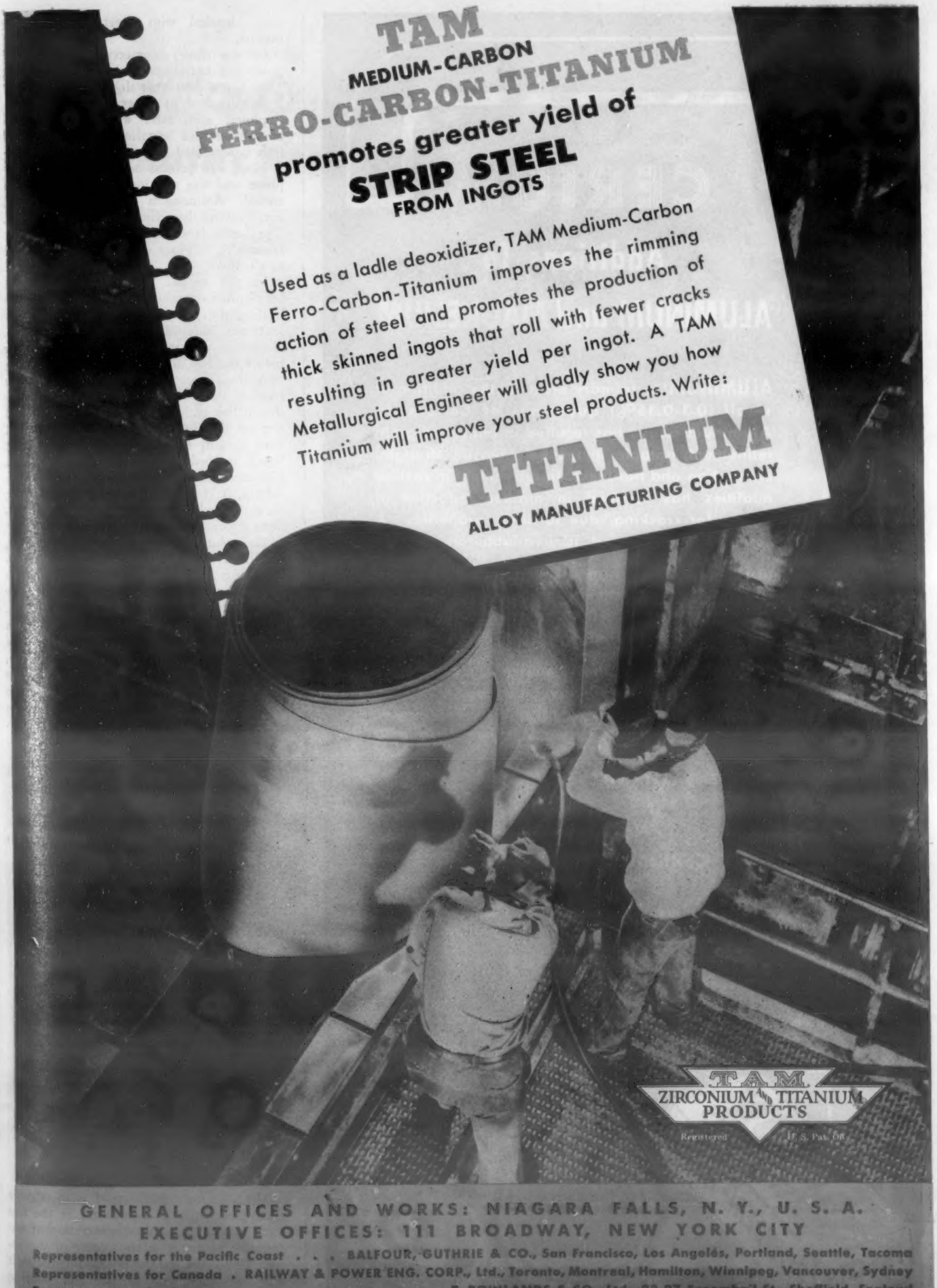
Beryllium Production

Condensed from "Mill and Factory"

"Beryllium is to copper what carbon is to steel". By addition of as little as 2% Be, copper can be given strength, hardness and endurance, or can be precipitation-hardened to increase its strength six times or more, making an alloy of the strength and hardness of high grade steel. Beryllium-copper is non-magnetic, has good electrical conductivity, and resists corrosion, high temperatures and fatigue.

The atomic weight of beryllium comes forth after hydrogen, helium and lithium. It can be made more ductile by the addition of titanium or zirconium. It is found in about 30 minerals, of which beryl is most common, a beryllium aluminum sili-

(Continued on page 998)


TAM
MEDIUM-CARBON
FERRO-CARBON-TITANIUM
promotes greater yield of
STRIP STEEL
FROM INGOTS
Used as a ladle deoxidizer, TAM Medium-Carbon Ferro-Carbon-Titanium improves the rimming action of steel and promotes the production of thick skinned ingots that roll with fewer cracks resulting in greater yield per ingot. A TAM Metallurgical Engineer will gladly show you how Titanium will improve your steel products. Write:
TITANIUM
ALLOY MANUFACTURING COMPANY
TAM
ZIRCONIUM TITANIUM
PRODUCTS
Registered U. S. Pat. Off.
GENERAL OFFICES AND WORKS: NIAGARA FALLS, N. Y., U. S. A.
EXECUTIVE OFFICES: 111 BROADWAY, NEW YORK CITY
Representatives for the Pacific Coast . . . BALFOUR, GUTHRIE & CO., San Francisco, Los Angelés, Portland, Seattle, Tacoma
Representatives for Canada . RAILWAY & POWER ENG. CORP., Ltd., Toronto, Montreal, Hamilton, Winnipeg, Vancouver, Sydney
Representatives for Europe T. ROWLANDS & CO., Ltd., 23-27 Broomhail St., Sheffield, England

cate, identical with emerald and aquamarine.

Of the three commercial processes for producing beryllium, two fuse the ore at 1500 C., or heat treat slightly lower. Then it is quenched in water and treated with sulphuric acid, after which the solution of sulphates of beryllium, aluminum and iron is separated from the solid silica.

Now, one process adds ammonium sulphate and the solution is evaporated and cooled. Ammonium alum is crystallized out, leaving beryllium sulphate solution. The latter is further evaporated and the crystals of sulphate decomposed into oxide in a furnace.

In the second process, separation of beryllium from aluminum is done by controlling the pH. Through the addition of ammonia, soda ash or other basic material, aluminum and iron hydroxides precipitate before the beryllium.

A third process renders the ore into a reactive state, separating beryllium in one step at low temperature. The ore is ground wet or dry in a ball mill. It is mixed with sodium ferric fluoride, the wet mix being tamped into briquettes heated in a tunnel kiln at 750 C. for an hr. After baking, it is ground in a wet pebble mill; then the only soluble part, sodium beryllium fluoride, is leached out with water.

The solution is treated with caustic soda, beryllium hydroxide precipitating, the latter being filtered and washed, the filtrate proving a solution of sodium fluoride. By heating the hydroxide cake to 800 C. anhydrous oxide results. From the sodium fluoride, treated with a sulphuric acid neutralizer and a ferric sulphate solution, sodium ferric fluoride is precipitated. The precipitate is filtered and the filter cake returned to the early stages of the process for mixture with the pulverized beryl ore.

To make beryllium-copper alloy, the beryllium oxide, carbon powder and copper powder (or oxide) are mixed and charged into an arc furnace, 25% Cu entering the mix. Larger pieces of copper are added periodically, the product being a master alloy, 4% Be, later reduced by copper to 2%.

—*Mill & Factory*, Vol. 34, June 1944, pp. 101-102, 304-308

Segregation in Rimmed Steel

Condensed from "Blast Furnace and Steel Plant"

The aim for rimmed steel is to effect a maximum negative segregation in the rim zone without excessive concentration of undesirable elements at the center of the ingot. To do this, the composition of the melt may be varied, and furnace and pouring practice may be adjusted.

Carbon and oxygen as carbon monoxide

and dioxide constitute most of the gas evolved during rimming. Rimmed steels approach the condition of maximum possible segregation because of the washing action of the liquid metal as it moves upward along the inside surface of the solidified metal.

Liquid movement results from gas evolution caused by formation of the oxides of carbon. Gas evolution will be much slower in the lower portion of the ingot.

It is evident that in the steels tested (0.075 to 0.81% C), oxygen must be the controlling factor in gas evolution, which will be the case also in higher carbon steels. With considerably lower carbon, around 0.03%, conditions are reversed, hence determined by the carbon. Manganese affects gas evolution much more in the lower part of the ingot than near the top.

The efficiency of washing increases as the sulphur decreases. The proportional segregation of sulphur actually increases as the sulphur increases. Several factors tend to make positive segregation in the core of the rimmed ingot greater than in a semi-killed ingot of the same ladle analysis.

The composition of the melt is an important factor in determining the degree of segregation in rimmed steel. Moreover, the concentration of carbon, oxygen and manganese affect the segregation of all elements.

The steel temperature and mold conditions, which govern the freezing rate of the steel in the mold, and the capping practice, which determines the extent of the rim zone, also have an important influence on segregation. Studies emphasize the importance of taking the bath to as low a carbon as practical before tapping to secure a high concentration of oxygen.

Adjustment of combustion and the timing of ore additions are the principal means of temperature control in the furnace. In finishing the heat, an addition of spiegel or pig iron a half-hour before tapping may be desirable to check the carbon drop momentarily.

Mold Wall Thickness

The effect of mold wall thickness is one of most importance in the solidification rate of the core zone, since, in the range of commercial mold thicknesses, this factor does not affect the freezing rate until the heat flow reaches the outer wall of the mold. Thus, the freezing rate during solidification of the rim zone is actually the same whether the mold is thin-walled or thick-walled.

A rectangular shape for a mold of given area is desirable on account of the shorter total time for solidification. It is best that the evolution of gas be checked as early as possible. This can be accomplished by placing a plate or casting on the molten metal surface, causing the metal to freeze and thereby sealing the ingot.

A representative capping practice for a slab mold 24 in. wide consists of removing the scum from the surface of the molten metal when the rim at the top is 4 to 5 in. wide, placing a 3/8-in. steel plate over the opening, and flooding the top with water.

Summarizing, the desirable type of segregation in the rimmed grade of ingot consists of maximum negative segregation in the rim zone and minimum positive segregation in the core. Finally, the composition of the steel with respect to elements that

are not subject to elimination from the ingot as reaction products must be held to low values, particularly when their segregation coefficients are high.

The desired vigorous motion of the metal, which removes rejected impurities from the solidifying surface, may be secured by maintaining a high carbon-oxygen product, a rapid freezing rate and a low pouring temperature.

—J. W. Halley & G. L. Plimpton, Jr. *Blast Furnace & Steel Plant*, Vol. 32, May 1944, pp. 539-546, 550; June 1944, pp. 683-688.

Making Alloy Steels to Required Hardenability

Condensed from a Paper of the American Iron and Steel Institute

In order to accumulate supporting data to establish ranges of hardenability commercially feasible to the steel producer, nine steel companies were asked to sample and test 26 heats, and the results were correlated by a committee. The steels used were popular types such as 1340, 2515, 3312, 4130, 4140, 4150, 4320, 4340, 4620, 4720, 8620, 8630, 8640, 9260, 9420 and 9440.

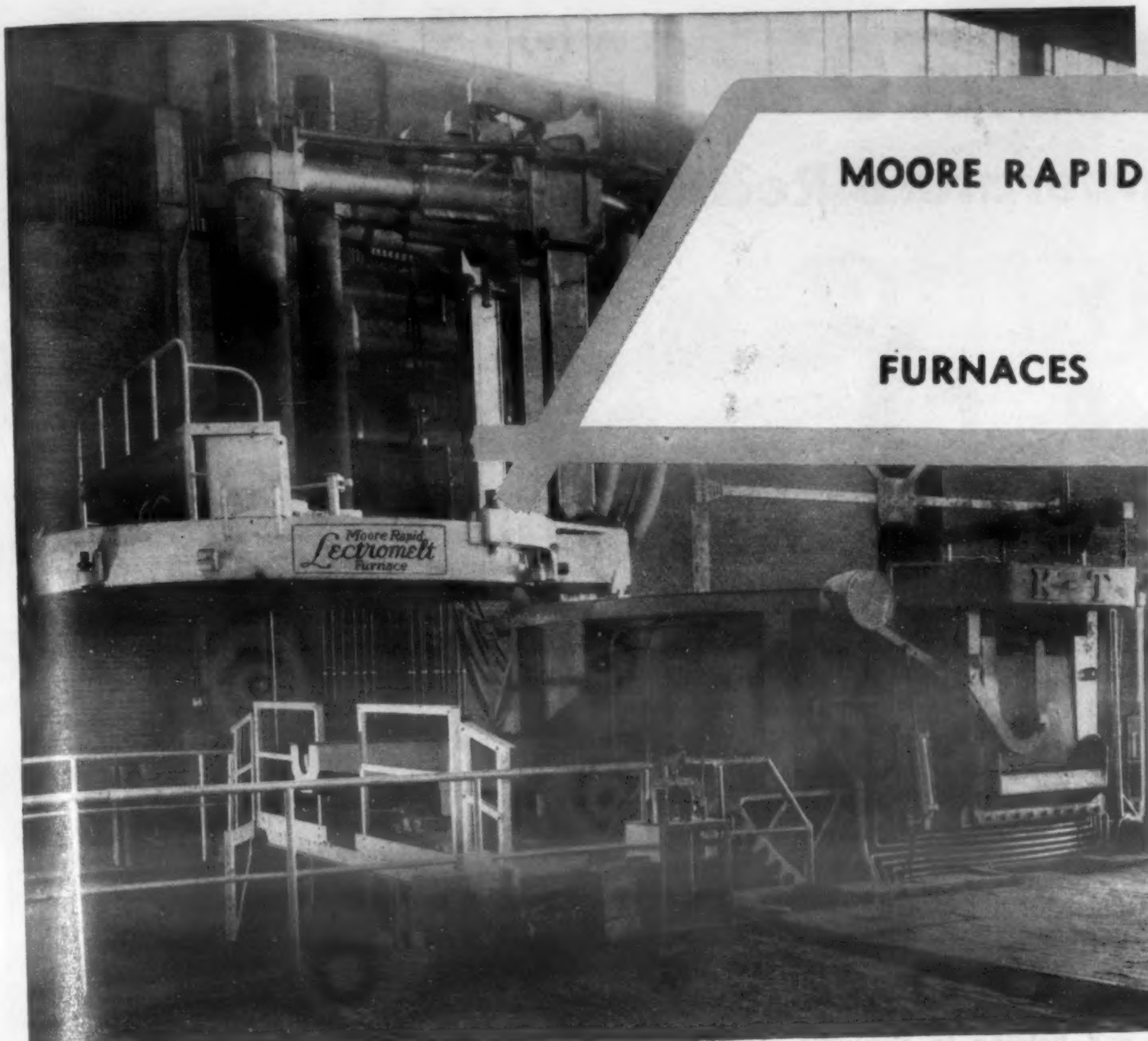
It has been established that a test bar cast at the time of ingot pouring, if proper size and relationship to the mold be used, would be representative of the metal cast into regular ingot molds, forged, normalized and machined to similar-sized test bars. That is, tests of cast test bars are comparable to results of forged and normalized specimens. Three types of steel, 4340, 8630 and 9420, were so compared, and results with forged specimens were determined for the others.

Summarizing all the data, it was found that in general the cast tests have a slightly lower hardenability than the forged specimens, but the difference is of minor importance in most cases.

To compare positions in the heat, cast tests were taken at the time of pouring the first, middle and last ingots. It was shown that variations are of the order of 1 to 1½ points Rockwell, and are so minor that one cast test could indicate the hardenability of the entire heat of steel.

In order to find out how closely two or more laboratories can check each other in hardenability results, samples were sent to nine mill laboratories and one consumer laboratory. Maximum variations of 5 or 6 points Rockwell hardness occurred on some curves, indicating that every effort should be made to standardize testing procedures.

It is fairly well established that hardenability is affected primarily by chemistry and the grain size of the test at the temperature used. The hardenability of the steel can then be calculated within reasonable limits. It was concluded that Grossman's factors would be used in all cases except those for manganese above 1.50%,



MOORE RAPID FURNACES

A size "KT" Lectromelt top charge furnace with roof rotated, ready to be charged by a drop bottom charging bucket. This is one of the heavy, steel mill type furnaces.

★Moore Rapid Lectromelt Furnaces are built in a wide range of standard sizes from 100 tons down to 25 pounds capacity. Almost all of the Lectromelt furnaces installed during the past few years have been of the top charge type. The top charge feature offers many advantages, such as greater output due to decreased charging time, lower power and refractory costs, increased production per man hour and many others. Especially large pieces of scrap can be charged readily, and light fluffy scrap can be charged to shell height with a drop bottom bucket. In some of the very large sizes—frequently arranged for installation on an open-hearth platform—a door charge furnace may be used with the charging being handled by an open-hearth charging machine.

The following tables list some pertinent data on the various sizes of Lectromelt Furnaces:

TABLE I. These larger capacity furnaces are of the heavy, steel mill type and are generally used for ingot production.

Lectromelt Size	Nominal Size of Heat	Shell Diameter	Nominal Capacity of Substation
HT	75-100 Tons	20′—0″	15,000 kva
IT	60-75 Tons	19′—0″	15,000 kva
JT	50-60 Tons	18′—0″	12,000-15,000 kva
KT	40-50 Tons	17′—0″	10,000-12,000 kva
LT	30-40 Tons	16′—0″	8,750-10,000 kva
MT	25-30 Tons	15′—0″	7,500 - 9,375 kva
NT	15-20 Tons	12′—4″	7,500 - 9,375 kva
OT	8-12 Tons	11′—0″	6,000 - 7,500 kva

TABLE II. The Lectromelt furnaces listed in this table are generally used in foundry work but many of these smaller furnaces are used in ingot shops for pouring billet size ingots or for tool steel.

Lectromelt Size	Usual Hourly Production Rate*	Usual Size of Heat**	Nominal Size of Substation
OPT	4½ Tons	8-9 Tons	3,000-3,750 kva
PT	3 Tons	5-6 Tons	2,000-2,500 kva
CQT	2 Tons	3½-4 Tons	1,000-2,000 kva
QT	1½ Tons	2½-3 Tons	1,200-1,500 kva
RT	1 Ton	2 Tons	800-1,000 kva
ST	1,000 Pounds	1 Ton	400- 500 kva
TT	500 Pounds	1,000 Pounds	300- 375 kva
UT	250 Pounds	500 Pounds	200- 250 kva

*On acid practice or single slag basic practice.
**The furnaces are so constructed that, when the occasion demands, especially large heats can be poured, considerably in excess of the "usual" heats listed.

TABLE III. The Lectromelt furnaces listed in this table are intended primarily for laboratory and experimental use. These furnaces are for operation from a single phase supply.

Lectromelt Laboratory Sizes	Usual Size of Heat	KVA Rating
V	200-300 Pounds	100
VW	100 Pounds	100
W	50 Pounds	50
X	25 Pounds	37.5

ARMY E NAVY

PITTSBURGH 30, PENNSYLVANIA

when the factors of Crafts and LaMont were used.

Results of comparisons of calculated with actual values indicated that the calculated hardenabilities are sufficiently close to justify their use for the theoretical establishment of spread bands. Maximum deviations in this series of tests were —9 and +6 points Rockwell.

It can be said, therefore, that the steelmaker apparently can use cast test pieces, one or more to a heat, and obtain reliable results indicating the average hardenability of the heat within reasonable limits of error. The method will permit a close check in results with the consumer on random samples.

—W. G. Bischoff. *Am. Iron & Steel Inst.* paper, May 25, 1944 meeting.

Flaking of Open Hearth Steel

Condensed from "Industrial Heating"

At the recent conference of the National Open Hearth Steel Committee of the American Institute of Mining & Metallurgical Engineers held in Pittsburgh, Pa., three papers presented before the British Iron & Steel Institute were reviewed.

In the first paper, "The Determination of the Solubility of Hydrogen in Iron and Iron Alloys," it was shown that, in pure iron, an abrupt change in hydrogen solubility occurs between 1742 and 1652 F. With the nickel-iron alloy, this discontinuity begins on cooling, at 1067 F., and continues to 887 F. In nickel steel, discontinuity extends from 1112 F. to 572 F.

The second paper, "The Formation of Hair Line Cracks," showed: Hair-line cracks (or flakes) induced by soaking alloy steels in hydrogen, followed by rapid cooling through the Ar_1 point, appear in an annular zone 3 to 5 mm. below the surface; cracks appear only when the quenching treatment is followed by an overnight aging period, are more pronounced in a nickel steel and a nickel-chrome-molybdenum steel than in a plain carbon steel, and are not so induced in sections under 2 cm. in diam., and form in forged but not in as-cast steels; if the steel is cooled to just below the Ar_1 point, no cracking occurs; steels quenched in hot oil show no subsequent cracking.

The microscope showed that the cracks found were mostly inter-granular, although some were trans-crystalline. It was also found that if the specimens were rapidly heated to 575 F. or higher before sectioning, white ferritic areas were usually formed around the cracks. They disappeared when the specimens were heated for two hr. at 1380 F. in vacuo.

Specimens tempered at 1200 F. showed a segregation of carbides in the vicinity of the cracks. This was not shown on specimens that had previously been soaked in vacuo or in nitrogen.

Conclusions Reached

The third paper further established the hypotheses advanced with the following conclusions:

Hydrogen is the fundamental cause of hair-line cracks; it is present as a hydrogen-rich constituent formed on rapid cooling through the gamma-alpha transformation range, breakdown of which releases hydrogen; even at room temperature the cracks contain methane as well as hydrogen; the influence of composition upon flake susceptibility is due to the effect of the alloying elements upon the stability of the hydrogen-rich constituent; cracks will not result if the breakdown of this constituent can be effected at sufficiently high temperatures.

A paper was then presented that outlined the two schools of thought as to the cause of flake formation in steel. In opposition to the idea that hydrogen is the fundamental cause, is the idea that it is only a contributory factor. It is believed that the stresses that accompany the volume change in transforming from gamma to alpha iron on cooling are the most potent factors.

It was pointed out that experimental inducement of flakes by application of hydrogen under laboratory conditions is very different from mill operations. Disruption stresses in rapidly cooled steels could be easily set up by both steep temperature gradiants and volume changes.

Control of flakes by thermal treatment after hot working—the use of bury pits—was then discussed. The best practical cycle is one that gives complete freedom from flakes and maximum softening of the steel. A typical cycle for SAE 4340 consists of cooling from 77 F. in nine hr., holding for seven hr., reheating to 1275 F. in 18 hr., holding nine hr., and cooling to 1000 F. in ten hr. In over 3000 heats so treated losses due to flaking were less than 0.5%.

It was concluded that control of flakes is a matter of such a suitable cycle and the control of the raw materials used in the melting process with elimination of as much moisture as possible.

—B. B. Rosenbaum. *Ind. Heating*, Vol. 11, June, 1944, pp. 932-934, 936, 938, 944; July, 1944, pp. 1110, 1112, 1114.

Sponge Iron

Condensed from "Iron and Steel Engineer"

Sponge iron has come to mean almost any kind of iron made directly from ore, except pig iron made in the blast furnace. Technically, it is iron reduced to metal from oxide without fusion. Except for a small amount of iron powder, no sponge iron is being produced commercially in this country at present.

The various processes for sponge iron fall into three groups: (1) Early high-temperature charcoal forge processes operating above 2000 F.; (2) more modern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licking them with a Taylor 'pedigreed' product. For example, Taylor Zircon refractories are 'best of breed' for aluminum open hearth furnace bottoms and side walls to metal line, resulting in cleaner metals — more production. Inquiries receive immediate attention and careful study by Taylor engineers. Write for Bulletin 200.
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medium temperature reduction processes, at 1600 to 2000 F.; and (3) the most recent low temperature gaseous reduction at below 1500 F., and probably between 1000 and 1100 F.

The first type died out during the 19th century. Two Swedish processes of the second type have been successful. In the modern processes using a solid reducing agent, the reaction is not between carbon and iron oxide, but between carbon monoxide and iron oxide.

Gas under pressure would increase the rate of reaction, but pressure with carbon monoxide would tend to form dioxide and carbon. Hence, hydrogen has been suggested for the third type of process.

Hydrogen makes possible operation at very low temperature, and so avoids sticking and sintering. One lb. of hydrogen has the reducing power of six lb. of carbon. It has never been given much consideration in the past because it was considered entirely too expensive to compete with carbon. This is no longer true.

A plant now being built at the Warren, Ohio, plant of Republic Steel Corp. for the Defense Plant Corp. utilizes coke oven gas as the source of hydrogen in the Brassert process for iron ore reduction. It is about 50% H. Since only one-sixth of the coke-oven gas is utilized in the reaction, the plant is designed to operate at only one p.s.i. maximum pressure.

The Process

The gas from the coke oven plant is further desulphurized, heated to 600 to 700 F. in a heat exchanger by spent gas, further heated to 1200 to 1300 F., and sent to a Herreshoff furnace. Here the hot gas is bubbled up through the fine ore on the bottom hearth. The gas zigzags in and out over each hearth, countercurrent to the ore, which similarly moves out and in over each hearth, dropping downward at the center and the periphery of every other hearth. The total volume of gas handled is roughly equal to that in a blast furnace.

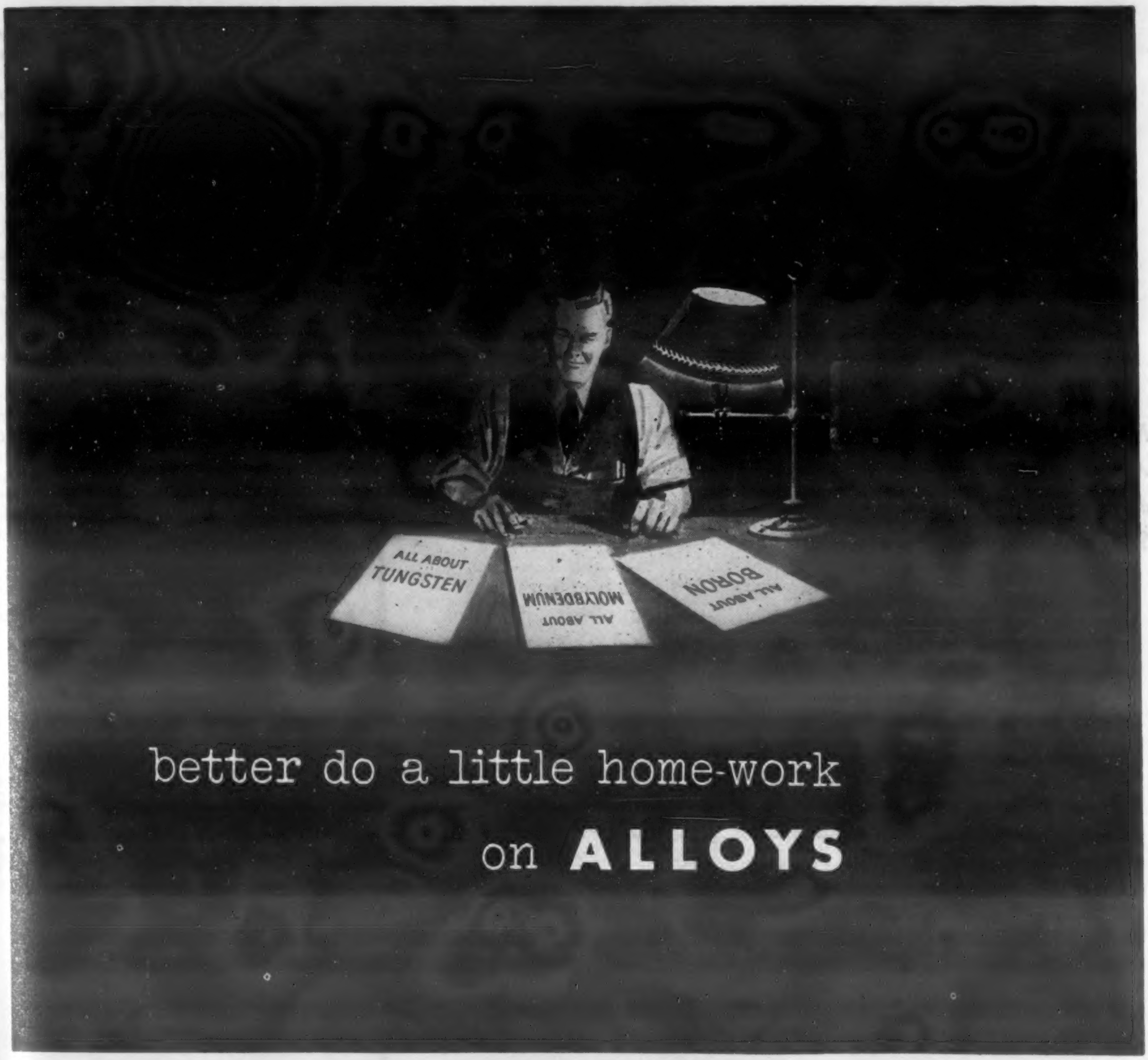
The ore at Warren is expected to be an Adirondack magnetite, all minus 10 mesh, with between 10 and 20% of minus 200 mesh material. Depth of ore moved on the hearths will be about 2 in. It will remain in contact with the hot gas from 8 to 12 hr. Projected capacity is 100 tons a day.

Somewhat more than half of the spent gas, after cleaning, is recycled through the system, the rest being returned to the steel works for use as fuel.

The Herreshoff furnace itself is the largest unit, being about 45 ft. high and 20 ft. in diameter. Combined volume of the heat exchanger and heater is roughly one-third that of the furnace.

For plants using commercially pure hydrogen instead of coke-oven gas, very high pressures and finely divided ore, say 60 mesh or finer, can be used. If hydrogen is recycled, bleeding must be resorted to in order to eliminate inert gases. About 20,000 cu. ft. of hydrogen per ton of sponge iron are required, instead of the theoretical 16,000 cu. ft. If operated at 450 p.s.i., the reaction would require only ½ hr.

—C. F. Ramseyer. *Iron & Steel Engr.*, Vol. 21, July 1944, pp. 35-44, 72.



The use of alloys has grown and is growing because the properties of metals for war purposes must go far beyond former requirements, and because alloying materials are now available in ever-increasing amounts, and because new metallurgical knowledge has improved the efficiency and the economy of employing such materials.

The end of the war will not reverse all this. In many quarters, rather, it will intensify competition and the urge to improve production at the lowest possible cost.

Molybdenum, Tungsten, and Boron have all been important to the war economy and each in its own way will be important to the economy of reconversion. The Molybdenum Corporation has prepared helpful information and advice on the most advanced applications of all these three much-discussed elements and the most approved techniques in using them. Correspondence is invited.

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Foundry Practice 2

Melting and Pouring of Gray Iron, Malleable, Steel, Brass and Bronze, Aluminum and Magnesium Castings • Molding, Core-Making, Gating and Risering, etc. • Foundry Furnaces, Refractories, Ovens, Molds, Sands, Binders, Auxiliary Equipment and Materials

CONTENTS

Malleable Cast Iron

Condensed from "Metallurgia"

Malleable cast iron may be one of two types—whiteheart or blackheart. The former, in the "as cast" condition, is a hard and brittle white cast iron, which must be subjected to a process of annealing to eliminate the hard iron carbide. It is essential that the analysis of the material be carefully controlled, particularly carbon and silicon contents, since otherwise graphite may form in the hard castings, making weak malleablized pieces.

A lower silicon content may be desired for heavy work, to prevent pregraphitization, while a higher content for light work helps in running thin sections. Difficulty in annealing, due to stabilization of the iron carbide, may result from too low a silicon content.

Carbon should be kept low in the original mixture, as it always tends to increase during melting. Undue reduction of carbon tends to impair the free running of the melt.

Annealing is not strictly the correct term to use in connection with malleable cast iron. The process is one of lowering carbon content of the white iron by oxidizing it at the metal surface. Castings are sealed in annealing pots with iron ore, and heated slowly and evenly. At about 730 C. (1340 F.) the ferrite starts to take free carbide into solution, and the process accelerates as the temperature reaches a maximum of 950 to 1000 C. (1740 to 1830 F.).

Carbon is being removed from the outer layers at this point, and gradually diffuses from the center of the work. This continues until the oxidizing effect of the ore is exhausted. The time required may vary from 100 to 200 hr. Remaining carbon is still in the combined state.

Blackheart malleable cast iron, like the whiteheart, starts with a hard white cast iron. Even more accurate control of carbon and silicon is required than for whiteheart, carbon ranging from about 2.40 to 2.70%, and silicon from 0.70 to 1.10%. A general rule is to vary silicon inversely with carbon to control graphitization.

In annealing for blackheart cast iron, the castings are packed in iron boxes or cans with an inert material, as black foundry sand, loam, pan-scaling or crushed slag. Annealing without packing material is possible, but increases the danger of distortion.

During the first stage of annealing, the heating and soaking of the castings, graphitization takes place, and is completed during the second or slow cooling stage. The work is heated slowly to about 750 C. (1380 F.), when austenite begins to form, then to 840 to 880 C. (1540 to 1620 F.), where it is held for 50 to 60 hr. Carbon is now deposited as temper carbon.

Cooling is held slow until 730 to 740 C. (1340 to 1360 F.) is reached, during which time carbon is deposited as its solubility becomes lower. Slow cooling to 680 C. (1260 F.) now precipitates the carbon remaining in the austenite. From 680 C. cooling may be fairly rapid.

—J. A. Wylde. *Metallurgia,* Vol. 30, July 1944, pp. 123-126, 129.

Reclaiming Foundry Sand

Condensed from "The Iron Age"

The Cincinnati Milling Machine Co. in 1939 planned a sand reclamation system for its new foundry in order to save money, dumping space for used sand, storage space for new sand, and cut down rail shipments.

Used core sand drops through an opening in the core digging room floor to a vibrating screen flooded by water sprays. The passed material drops into a sump and is delivered to the reclamation system, while the retained material is delivered to the lump crusher.

The sand in water suspension enters the dewatering tank from which the settled sand is carried by slow moving flights on an incline to a short belt and then dumped into an accumulation bin. From the accumulation bin, the still very wet sand is picked up by a one ton grab bucket and dumped into a muller for five min. of thorough scrubbing.

It is discharged from the mullers into a hopper, and a moving belt carries it at

(Continued on page 1014)

a measured rate into the classifiers. As the dirty sand passes through the classifier cells, the unwanted material is rinsed out and the clean sand settles to the bottom.

The classified sand is discharged into a sump and pumped to a continuous centrifuge to be removed from the water suspension. Then it is fed into a steam heated drum drier by screw conveyor. Control of steam pressure in the drier permits sand to be completely dried, or dried to any desired water content.

Used dirty water is withdrawn from the system at the dewatering tank, classifier overflow, and centrifuge machine and passed through the water clarifier. The reclaimed water is fed into the sump at the core digging stations, lump crusher sump, and classifier.

The clarifier also reclaims water from the foundry dust suppression system. Reclaimed water is handled in a pipe system separate from the new water. Sludge from the clarifier is continuously pumped out to a disposal area.

Sand reclaimed in this system is used as the equivalent of new sand. In a test, separate batches of new and reclaimed sand were mixed with like amounts of linseed oil and water, and tested. Results indicated the reclaimed sand to be at least equal to new sand, since the dry tensile strengths were equivalent, and the permeability of the reclaimed sand was higher.

A second test, using all the ingredients usually used in core mixes, was made. Again dry strengths and permeability of the reclaimed sand were favored by comparison.

The system has reclaimed 13,500 tons of used sand and used 65,000,000 gal. of processed water during one yr. of operation.

—William Rengering & Walter Horth. *Iron Age*, Vol. 154, July 6, 1944, pp. 68-74.

The Lost Wax Process

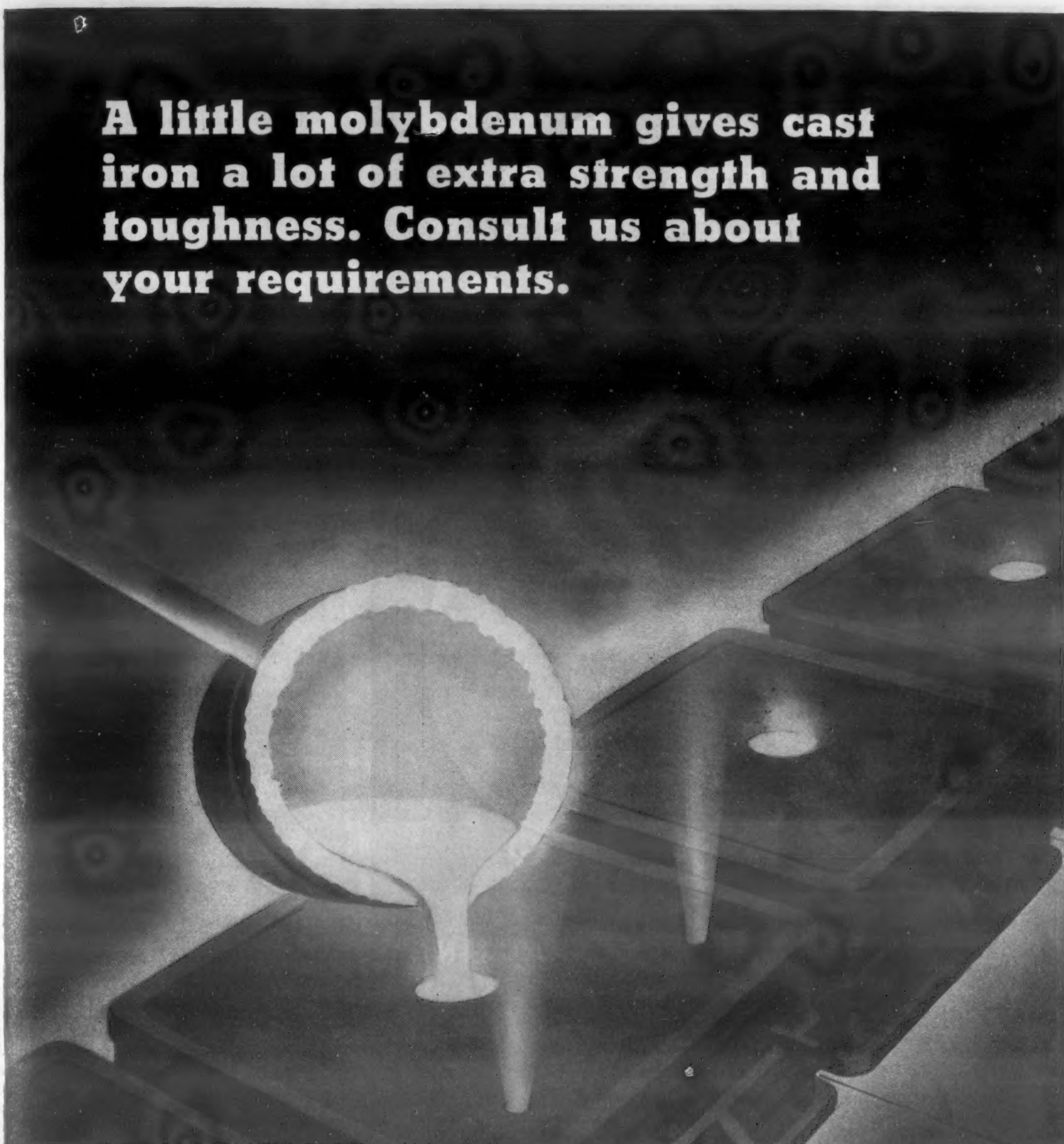
Condensed from "The Foundry Trade Journal"

In the lost wax process, a pattern of wood or other material is made true to size and shape without taper or loose pieces. Over this a quick-setting investment, such as plaster of paris, is molded, having as many partings as are necessary for the various pieces of the investments to be removed without difficulty when they have set hard.

After the pattern is removed, the investment is again pieced together and used to produce a number of wax patterns. A number of these wax patterns are placed together with a suitable sprue from each joining to a central runner.

The whole group is then encased with a suitable material to form a new mold and, after setting, the wax is melted out. While still hot, molten metal is run or forced into the mold.

The original pattern is not lost, and any number of wax castings may be made. Though a ceramic material is generally used for the mold, it seems reasonable to suppose that sand with a suitable binder,


A little molybdenum gives cast iron a lot of extra strength and toughness. Consult us about your requirements.

such as core gum, could be employed, providing the material would dry sufficiently to cause the investment to set sufficiently hard to keep its shape during the melting out of the wax pattern and the subsequent baking.

The process is used for small intricate castings weighing a few ounces, and it is claimed that the casting can be of such accuracy that no subsequent machining is necessary. Castings in yellow brass and various bronzes are readily made, and some degree of success has been achieved with iron and steel.

—J. F. Driver. *Foundry Trade J.*, Vol. 73, July 6, 1944, p. 186.

Centrifugal Casting

Condensed from "The Foundry"

Most metals can be cast centrifugally; exceptions are high phosphorus non-ferrous alloys, which wet the mold and stick badly, high-leaded alloys with 20% or more Pb, which tend to "centrifuge", alloys that are not suitable to the application without further heat treatment (cast iron in permanent molds), and alloys that are hot short and possibly may crack at high speeds (thin-walled sections of silicon bronze which needs extraordinary control of temperature and metal handling.)

Metals that can not be rolled or extended satisfactorily may be successfully cast centrifugally. Composite metal parts, such as a high-chrome steel ring with a lower grade backing, are possible by centrifugal casting.

Size and shape are limiting factors in centrifugal casting. Size is governed by the capacity of the equipment available, and by economics. With regard to shape, symmetry is necessary because of high stresses developed by unbalanced loads.

This point, and several others relating to design of centrifugal castings, are summarized as follows: (1) Counterbalance is used when necessary to establish diametrical balance in the casting about axes of rotation; (2) Non-cylindrical or slotted bores in uncored openings so far have not been cast successfully by the centrifugal method; (3) For centrifugal casting of a propeller, correct speed of rotation for hub could cause force on blade ends to go beyond limits of machine, but reduced speed would result in parabola formation at hub.

(4) Shrinkage common at center of ring blanks with heavy cross-sectional area may be offset by adding stock in the bore; (5) Non-ferrous castings with vertical bore and outlying details at right angles have definite limitations because of dross entrapment; (6) Castings requiring cored openings are apt to crack unless collapsible center cores are used to permit contraction.

(7) Centrifuged method or static pouring is preferable when it is necessary to insert pin cores in the area of the surface for bored holes; otherwise metal will wash cores away or show flow lines; and (8) Spun holes having diameters of less than one in. are generally impractical.

Although the initial costs of centrifugal casting may be higher than those for static

casting, the differential is frequently overbalanced by the following advantages: (1) High quality of the casting, (2) greater yield, (3) savings in machining costs, (4) limited equipment need, and (5) maximum production with limited space.

—John Putchinski. *Foundry*, Vol. 72, Aug. 1944, pp. 84, 190, 192, 194.

Microshrinkage in Light Alloys

Condensed from "Light Metal Age"

Microshrinkage occurs in magnesium-base alloys, certain aluminum-base alloys, and some copper-base alloys. Microshrinkage consists of microscopic, more or less connecting cavities that form during the period when solidification shrinkage takes place. These voids are located at positions remote from the riser where the solidification of intervening metal reaches the mushy stage and will not allow the passage of molten feed metal to compensate for the shrinkage.

The severity of microshrinkage is increased by (1) low temperature gradients between the point of initial solidification and the riser, (2) a wide solidification range of the alloy being cast, and (3) small amounts of eutectic liquid being formed.

Microshrinkage can be minimized by proper design of the part, by the intelligent use of chills, by the proper application of gates and risers, and by altering the composition of the alloy if such a change is permissible.

Casting stresses and gas in the melt are stated to be possible causes of microshrinkage. Casting stresses should be discounted, but dissolved gas may accentuate microshrinkage.

—L. W. Eastwood. *Light Metal Age*, Vol. 2, May 1944, pp. 12-14.

Heat Treating Steel Castings

Condensed from "Foundry Trade Journal"

At the time when it was decided to adopt the carbon-manganese steel, the standard heat-treatment for low carbon steel castings was a simple normalizing treatment of 4 hr. at 900 to 940 C., cooled in air, the castings being treated in bogie-type furnace fired with pulverized fuel. Ultimate stress showed a fairly consistent increase with rising carbon and manganese content, the former being much more potent.

Yield point is relatively stable in the lower ranges, but begins to increase sharply in the regions of 0.27 C with 1.55% Mn and 0.25 C with 1.65% Mn. In this region air-hardening tendencies begin to develop.

Elongation showed a steady decrease with rising carbon and manganese, the decline being more marked above 0.25% C. The compositional limits finally adopted are given in a carbon-manganese chart.

Heats with analysis falling within these limits can normally be expected to give satisfactory test results after standard heat-treatment. Heats low in carbon and/or manganese were dealt with in two ways. Those slightly below the desired standard can sometimes be sufficiently improved by full air cooling instead of the normal bogie cooling. This was effected by pulling the castings from the furnace and placing them on the floor to cool separately. This gave

between 0.5 and 1.0 tons p.s.i. gain in yield point at a slight sacrifice to elongation.

Heats appreciably below the desired limits were salvaged by water-quenching and tempering. Heats slightly above the desired limits were sometimes sufficiently improved in ductility by tempering after normalizing.

Results from this method are somewhat unreliable, high manganese with fairly high carbon content frequently giving very poor elongation values. Most of these heats were brought within specification by water-quenching and tempering.

A factor of great importance is the temperature to which the castings are allowed to cool before removal from the quench. Two bars were heated for 4 hr. at 900 to 920 C., one being quenched in cold water until cold (15 C.) and the other quenched for 30 to 40 sec. and then removed at a temperature between 250 to 350 C. After allowing the latter to cool in an air to about 100 C., both bars were placed in a furnace at a tempering temperature of 550 to 600 C. and tempered for 3 hr.

The bars removed warm from the quench give somewhat better physical properties in all respects than those fully quenched. It seems that the greater internal stresses set up by the full quench have a detrimental effect even after tempering.

For the test-pieces quenched from 910 C. in cold water (15 C.), the yield point and ultimate stress fall steadily with increasing temperature, while elongation and reduction of area show a corresponding increase. Contrary to expectations, the impact value also declines in the range of 550 to 650 C. This might be due to the progressive coalescence and coarsening of the structure.

Excellent properties can be obtained over a wide range. If high strength is the main object, it can be obtained by tempering at a lower temperature, such as 450 C., where ductility is still at a high level.

In practice, it would probably be better to choose a composition permitting the use of higher temperatures, as higher temperatures give exceptionally good ductility and more complete stress relief while retaining a yield point still considerably above that given by normalizing.

Carbon-manganese steel is sometimes accused of temper brittleness. In all castings of normal section, air cooling after tempering is sufficiently rapid to prevent any embrittlement. For the same carbon and manganese content, converter steel has a higher yield point and a higher ultimate stress than basic electric steel.

The yield ratio is lower. Elongation and ductility in general are poor and less consistent. This is often attributed to grain boundary inclusions, due to unsuitable deoxidation procedure, but unsatisfactory elongation sometimes occurs with random distribution of inclusions. More drastic heat-treatment is necessary to refine the structure.

Impact values are generally lower and more variable. The greater resistance to breaking down necessitates a higher temperature (940 to 960 C.) and leads to some coarsening of grain. It is necessary to employ double normalizing from 950 and 850 C. to obtain results comparable with the single normalizing treatment used for the basic electric steel.

—T. W. Ruffle. *Foundry Trade J.*, Vol. 73, July 13, 1944, pp. 215-220.

Metal-Working and Treating

Die Casting • Powder Metallurgy • Drop, Hammer and Upset Forging • Press-Forming, Drawing, Extruding and Stamping • Machining, Grinding and Polishing • Hardening, Tempering, Age-Hardening, Annealing and Malleableizing • Carburizing, Nitriding and Surface Hardening, Heating Furnaces, Refractories, Fuels and Auxiliaries • Welding, Flame-Cutting, Hardfacing, Brazing, Soldering and Riveting • Cleaning, Pickling, Degreasing and Sandblasting • Electroplating, Anodizing, Galvanizing, Metal-Spraying, Coloring, Buffing and Organic Finishing

CONTENTS

Heat Treating Furnaces

Condensed from a Panel Discussion, American Society of Mechanical Engineers

[The A.S.M.E. recently held a panel meeting in Pittsburgh on "Industrial Furnaces," at which 22 papers were presented on various aspects of furnace design and application. This digest is a condensation of the official summary of the meeting prepared by Professor H. C. Hottel of the Massachusetts Institute of Technology.—The Editors.]

Induction heating has contributed to furnaces in that it offers a possibility of eliminating them. In induction heating, the work is simply surrounded by the current-carrying conductors so as to produce a desired heat pattern. By correctly controlling the kilowatt input per sq. in. of surface, it is possible to heat so rapidly that scaling and oxidation will be negligible.

When controlled atmospheres are used in furnaces, the load-carrying properties of the insulating firebrick may be affected. Reducing atmospheres seemed to cause greatest change, and the carbon dioxide content appeared to be responsible.

High-temperature forced convection heating has brought such engineering problems as circulating fans doubled in size, retention of furnace component alignment at high heat, protection of refractories against erosion by hot rapidly circulating gases, and water cooling of shafts and bearings.

Special furnace atmospheres have made possible bright gas quenching, recarburization of decarburized work, clean forging, and gas pickling.

Heat enduring chrome-nickel alloys for furnaces include 65 Ni, 17% Cr, for carburizing boxes and retorts; 35 Ni, 15% Cr, for furnace construction where combustion products do not contain substantial amounts of sulphur, and 25 Cr, 10% Ni, the least expensive and showing 30% greater hot strength than the 35-15 alloy.

Four Automatic Operations

A single completely automatic unit is now doing four operations on a tank part—copper brazing at 2025 F., partial cooling to 1100 F., reheating to 1550 F. then oil quenching.

Induction heating, with its automatic regulation of power and split-second control, makes possible the production of locally hardened objects with the desired depth and degree of hardness and lack of distortion and of scaling. Gas heat is also controlled, directed, and patterned in furnaces a fraction of former size by means of completely burning gas-air premixtures at high rates.

The factor of rate of transfer of heat in relation to the composition and geometry of the work should help to determine the rate at which heat should be transferred, rather than that at which it can be transferred.

Electric arc melting furnaces have shown a number of improvements recently, including the following: Life of roof rings and top courses of sidewalls improved by insertions of water-cooling pipes; use of

(Continued on page 1026)

larger roof rings has increased life; use of a new water-cooled electrode cooling gland; hydraulic control of electrodes; use of rotary-type automatic regulators, and standardization upon the top charge type of furnace.

A recent outstanding development is the use of the electrode furnace with the salt bath heated in a ceramic pot. The ceramic pot permits maintaining the bath free from iron oxide, while the use of electrodes permits generation of heat in the bath.

Scaling Reduced by Control

It is possible, in billet-heating furnaces having the best possible control of combustion, to reduce the amount of scaling and depth of decarburization to one-half that in furnaces having no control.

Separately prepared furnace atmospheres are rapidly expanding in use in industrial heating furnaces and metallurgical processes.

Use of suitable refractory pots for neutral hardening has, more than any other single factor, permitted expanded use of salt baths. Metallic pots are still preferred for cyanide and nitrate baths.

About 75% of the total heat absorbed by steel billets in normal heating operations enters in the first half, or cold half, of the furnace.

By use of cooling air from the discharge end of an enamelware kiln for combustion of fuel gas, fuel savings averaging 20% have been made. The principal is used in kiln firing from 1400 to 3100 F.

Carbo-nitriding, in which both carbon and nitrogen are imparted to ferrous pieces by a gaseous atmosphere, can duplicate the usual cyanide case, or can be used to confer air-hardening properties on the case in carbon or low-alloy steels.

By rematching the generator in a high frequency induction furnace to the low power absorption of the metal above the point of loss of magnetism, the rate of power absorption can be made constant, and higher temperatures reached in a shorter time and with a smaller unit than would be possible otherwise.

—*Am. Soc. Mech. Engrs.*, panel discussion, June 19, 1944.

Zinc Plating as a Draw Lubricant

Condensed from "Monthly Review," American Electroplaters' Society

A soft ductile plate must be used as a "lubricant" in the deep drawing and ironing of steel. Several plates have the desired properties, but the most economical was found to be zinc. A standard cyanide zinc bath will give a suitable plate, but this type bath with certain modifications will give a more ductile plate that is better suited to drawing and ironing applications.

The thickness applied must be carefully controlled because of the close tolerances between the dies and punches. The G.E. Gage and the Magna-Gage provide convenient tools for this purpose.

Cleaning before plating involves several operations. Where oil or drawing compounds are used in earlier operations, the

work is vapor degreased and then annealed to relieve drawing stresses. After annealing, the work is quenched and pickled in an automatic pickler to remove annealing scale.

The iron and acid content of the pickle are closely controlled, and an inhibitor is used. To prevent rusting after pickling, a tri-sodium phosphate dip is used. The work then passes through an anodic cleaner, an alkaline rinse, a water rinse, a sulfuric acid rinse, two neutralizing rinses, a sodium cyanide rinse, and then passes into the plating bath.

In this installation, insoluble anodes are used for inside plating, necessitating frequent replenishment of the zinc content of the bath. Replenishing solution is purified in a separate tank by the addition of sodium sulfide. The purified solution is then filtered into the plating bath.

The bath is thoroughly agitated and continuously filtered at a rate that gives a complete turn-over of the bath every eight hours.

After the work is plated, rinsed and hot air dried, it is given a coat of molten soap, again hot air dried, and started through the remainder of the ironing and drawing operations.

Following final drawing, the work is passed on a conveyor through spray cleaning, Cronaking, and rinsing operations.

—Harold A. Shepard. *Mo. Rev.*, Am. Electroplaters' Soc., Vol. 31, July 1944, pp. 613-618.

Annealing Steel Castings

Condensed from "Archiv Eisenhüttenwesen"

Investigations of castings from different melts with little chromium and chromium-molybdenum showed that a completely transformed structure and good mechanical properties can be obtained with adequate duration of annealing very close below or above the GOS line. A pronounced effect of a very definite annealing temperature could not be established.

Elongation and reduction of area show, in general, better values at or slightly above GOS. Chromium or chromium and molybdenum produced an improvement only in converter melts for notch-impact toughness and mechanical strength.

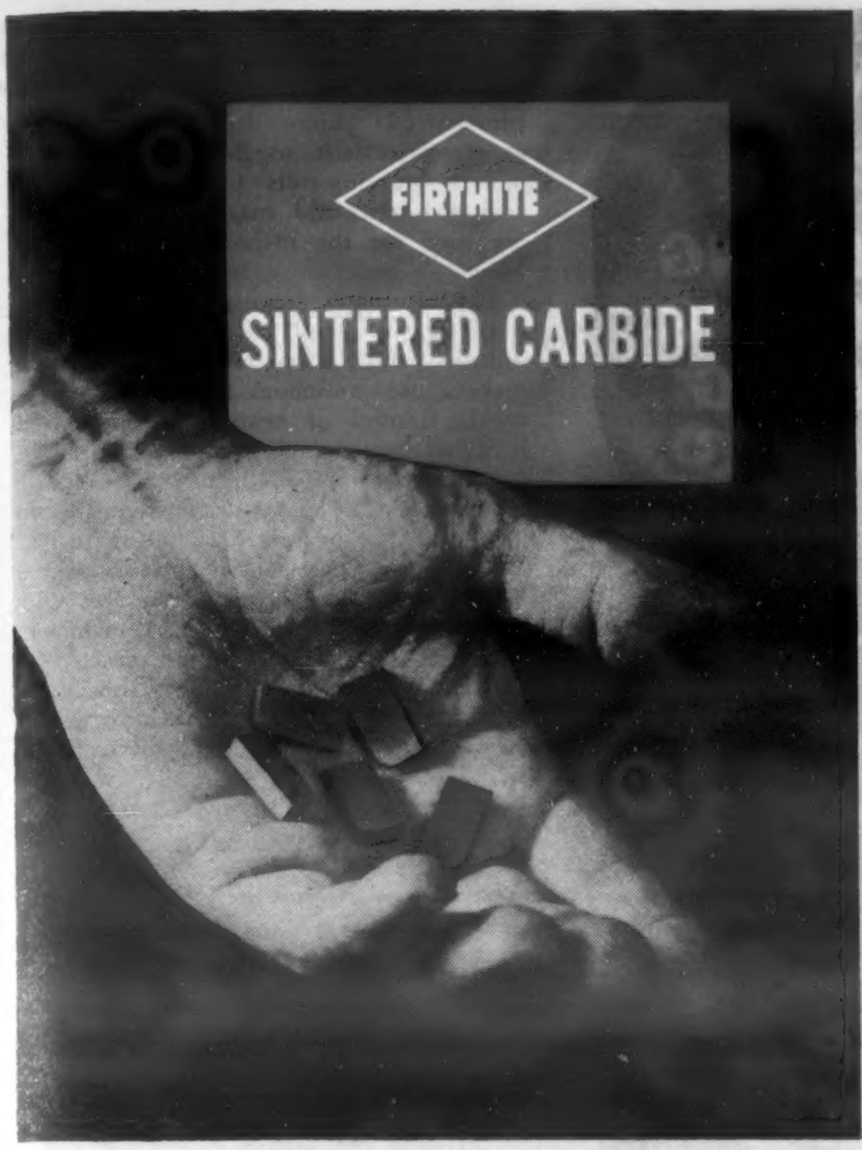
Notch-impact toughness, elastic limit and tensile strength are lower after cooling in the furnace than in air. Elongation and reduction of area did not show a difference for these two cooling methods.

—A. Evers & E. Piwowarsky. *Arch. Eisenhüttenw.*, Vol. 17, July/Aug. 1943, pp. 35-42.

Forging in Mass Production

Condensed from "Western Metals"

A forging is a piece of metal that has been heated to render it plastic, and was then subjected to mechanical working, thus changing its shape. Forgings of the highest possible quality must be produced at a cost such that the widest possible market can be covered competitively.



THERE ARE PLACES FOR BOTH . . .

Firth-Sterling, long specialists in making steels for shop tooling, early recognized the possibilities of carbides as a means of extending the improvement in shop practice brought about by the super high-speed steel—CIRCLE C. **But, there is a place for both . . .**

Where the highest speeds are obtainable or materials are hardest, FIRTHITE is the "last word" in a cutting material. It is used at speeds up to ten times those possible with high-speed steels. Where speeds above average are permissible or materials are "on the hard side," CIRCLE C will cut *at least* 25% faster than ordinary grades of high-speed steel. Send for descriptive literature on these remarkable materials.

For instance:

FIRTHITE *removes* 730 pounds of gray-iron casting metal per hour instead of 180 pounds;

drills a gun barrel in 23 minutes instead of 1 hour;

enables milling-cutters to run at 1,000 feet per minute instead of 100 feet with previous materials.

For instance:

CIRCLE C *machines* hard die blocks in 28 hours instead of 42 hours . . . doubling production between grinds — versus regular high-speed steel;

turns two to ten times more pieces of heat-treated alloy steel between grinds than other high-speed steels.

See the Firthite Movie to be shown in Booth No. B-146 at the National Metal Congress, Cleveland, O., Oct. 16 to 20, incl.

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Offices: McKEESPORT, PA. NEW YORK - HARTFORD - PHILADELPHIA - CLEVELAND - DAYTON - DETROIT - CHICAGO - LOS ANGELES

Equipment used to shape the metals includes: (1) Open frame hammers; (2) drop hammers; (3) steam and hydraulic presses; (4) motor driven presses, such as eccentric shaft, toggle, and percussion; and (5) forging rolls. Chemistry, the deep acid etch test, and magnetic examination are used for the inspection of bars and billets.

Batch furnaces are usually used in jobbing forging shops because of their flexibility. Larger shops, such as crankshaft makers, use continuous mechanized equipment. Control of heating is emphasized to avoid excessive surface decarburization, burning and internal rupture.

Proper die design enters materially into the economics of forging costs. Principal factors that govern and control both die life and the rate of production are: (1) Type of material; (2) sizes of hammers available; (3) weight of the piece; (4) forging temperature; and (5) shape of the part, which would include such design factors as drafts, radii of corners, fillets, etc.

Increase in carbon content of the forged material adversely affects die life. Using SAE 1020 as a basis of comparison, 0.30% C steel reduces die life 5%, 0.40% C about 7%, 0.50% C about 14%, 0.80% C about 35%, molybdenum steels with 0.30% C about 24%, and molybdenum steel with 0.50% C about 28%.

Chrome-nickel and chrome-vanadium steels are even more severe on dies and reduce the expected die life 37% for 0.30% C and 41% for 0.50% C steels of these analysis. Stainless steels, such as 18-8, indicate an expected die life of only 30% to 35% of that experienced with SAE 1020 steels.

While it is possible to make forgings of practically any design and dimensional tolerance, unusual limitations increase the costs of production. Close cooperation of the forging designer, the machinist and the forge shop are needed to produce ideal results.

—W. A. De Ridder. *Western Metals*, Vol. 2, July 1944, pp. 7-11.

Welded Ships Without Distortion

Condensed from "The Welding Engineer"

A fundamental difference between riveting and welding is that a negligible expansion occurs on riveting, but an appreciable shrinkage on welding. The locked-up stresses resulting from the shrinkage of the welded joints on cooling can cause fractures. Therefore, the order and method of welding must be such as to minimize locked-up stresses.

There are seven rules to be observed for minimum locked-up stresses: (1) Allow for weld shrinkage in lofting. The templates should be expanded and excess material left where necessary; (2) erect and weld so as to allow shrinkage toward the point of welding; (3) when welding a rigid unit, start in the center and weld toward the free edges; (4) weld the junctures of the framing before the framing is welded to the plating; (5) no member should be welded to another

member until shrinkage has taken place in both (exception—if both can be shrunk evenly after welding); (6) consider the many factors that affect welding shrinkage (for example, single pass welding is best as there is only one shrinkage); and (7) for the sake of fairness (which affects the strength of the hull), welding should be kept evenly balanced both vertically and horizontally.

A reheating of the weld to relieve the stresses is practical only on sub-assemblies. Flame shrinking or flame straightening may eliminate buckling and make the structure fair to the eye, but opposing stresses may still remain due to over- or under-shrinkage, usually the latter. Also, heating and rapid cooling is very deleterious to high tensile steel with about 0.3% C. Moreover, flame shrinkage requires extra man-hours. It can be almost entirely eliminated through the use of the proper erection and welding sequence.

A general description of the problems of pre-fabrication, sub-assembly and erection is given as exemplified by the hull structure, deck plates, bulkheads, double bottoms, side shell, etc. Unrestrained shrinkage should be allowed on sub-assembly as well as on erection on the ways.

The shrinkage of the longitudinal seams on shells is transverse to the hull and not as dangerous nor as great as longitudinal shrinkage, since the hull receives more longitudinal than transverse stresses. The transverse shape of the hull does not greatly restrain shrinkage, except in the dead flat section near midship.

In the straight part of the shell, the locked-up stress in the long seams can be reduced by peening or strongbacking. Proper strongbacking contributes to the overall strength of a welded hull. If a welded vessel is properly constructed, it is relatively stress free and is stronger than a riveted hull.

—M. Q. Cellers, *Welding Engr.*, Vol. 29, July 1944, pp. 35-39.

Hot Forming Magnesium Sheets

Condensed from "The Iron Age"

The light weight of magnesium alloy has constantly spurred the exploration of the possibilities of its use in aircraft. Castings, forgings and extrusions have been found to have practical applications in aircraft, but so far sheet has been restricted to fuel tanks and nonstructural parts requiring very little or no forming. Its disadvantages are low ductility in the cold state, susceptibility to corrosion, and high notch sensitivity.

The following alloys were tested: Dow Chemical Ma, J-1h, and O-1 HTA; American Magnesium AM-C52S-O and AM-C52S-H. The hard rolled material was used, and should be used only on parts with moderate or no forming and requiring high yield.

For the same weight, magnesium alloy skin has greater bending stresses and stability than aluminum alloy. In most cases, magnesium alloy has greater strength-weight ratio than aluminum alloys, although the magnesium gives greater deflection.


W
W
W
W
W
W
W

However, for equal weights, the two materials will have approximately the same deflection.

On monocoque structures or web beams, the substitution of magnesium for aluminum will result either in a big weight savings or an increase in the lateral stiffness of the sheet.

Magnesium alloys harden rapidly when formed cold; therefore, most successful forming is done at 300 to 750 F. The heating temperature for hard rolled material must be limited to avoid annealing.

In drop hammer forging, cold Kirksite dies and lead punches were used. The blanks were painted with one part of colloidal graphite in oleum spirits mixed with 50 parts of carbon tetrachloride before heating. For severe forming, the blank may have to be reheated two or more times before the forming is complete. Generally, magnesium alloys have more spring-back than aluminum alloys, and the dies must be designed accordingly.

In hydropress forming, the heat was applied to the form blocks by placing them on top of an electric hot plate. A heat resisting rubber blanket had to be used to protect the regular rubber pad in the platen. Flaked mica had to be sprinkled on the parts and hot plate to prevent the rubber sticking.

Stretch flanges formed well if the radius was not too sharp and stretching was confined to one direction. Depressed beads formed better than raised beads. Lightening holes should be made with a flat bottom and the holes cut after forming.

In brake bending, warping was encountered due to the uneven temperature of the sheet. Therefore, forming should be done so the whole cross section can be heated uniformly.

Dimpling is best done at elevated temperatures, as with a heated punch and die. Cracking of the dimpled sheets may occur during riveting, especially if a vibrator is used, unless extreme care is taken. Full-size holes may be drilled prior to dimpling with no trouble. Also, punched rivet holes were not detrimental. The fatigue endurance is increased more by an increase in sheet gage than by an increase in rivet diameter.

—E. P. Reson. *Iron Age*, Vol. 154, July 27, 1944, pp. 42-48.

Cushions for Tipped Tools

Condensed from "American Machinist"

Statements made by Frederick W. Taylor that tools failed through abrasion and finally through heat softening were not complete. His theory does not explain why a high-speed tool with a Rockwell 66 C will often have a shorter life than one with 63 C.

Many tests have been made without observations as to what took place during the cutting operation. Tests showed that the first phase of dulling can be explained as the minute chipping of the cutting edge. Some sections were larger than others, and when the tool failed, these large and small sections accounted for the irregular ap-

pearance of the wear lands. Gradually, abrasion or erosion would destroy evidence of the minute chipping of the cutting edge.

Minute chipping explained why a tipped high-speed steel tool of the same hardness and composition as a solid high-speed steel tool would give greater life between grinds. Initial chipping was greatly delayed on the tipped tool.

By introducing a "cushion," a copper between the high-speed steel tip and steel shank, a better shock absorber would be provided than by a plain brazed tool. Tools with high-speed tips of various hardness were made with 1/64-, 1/32- and 1/16-in. copper shims for cushions.

Tests on SAE forging, Brinell hardness 375 to 415, showed that the solid tool performed best at Rockwell 63 C, and was of no value at 65 C. At 64 C this tool machined seven forgings between grinds. A plain brazed tool without a cushion reached its peak at Rockwell 64 C. At this harness it machined an average of 26 forgings.

A cushioned tipped tool with a 1/32-in. cushion showed best performance at Rockwell 67 C, and machined an average of 52 pieces. Chipping was reduced and, thus, cushioned tools were dulled more through abrasion than through chipping. The land was uniform and smooth.

Solid tools machined 80 to 90 crankshafts in an automotive plant, 18-4-1 solid high-speed tools giving best results at Rockwell 63 C. With 12% cobalt tools 500 crankshafts were machined. Tools had a tip hardness of Rockwell 67 C.

Conventional carbide-tipped tools machined on an average of 44 armor-piercing shells, while cushioned-tipped carbide tools with the same grade of carbide averaged 108 shells.

Since tipping of tools with high-speed steel is not economical when the tool is less than ½ in. square, cushioning is done by attaching a 1/32-in. cushion on the bottom of a solid bit.

—Leo J. St.Clair. *Am. Machinist*, Vol. 88, Aug. 3, 1944, pp. 83-85.

Blanking Sheet Aluminum

Condensed from "Aviation"

The most common method of blanking aluminum is in a mechanical or hydraulic press. The punch is usually made of annealed steel, while the die is of hardened tool steel. The faces of the punch and die must be ground to keep cutting edges sharp, otherwise burrs will result.

Correct clearance between the punch and die is determined by the type and thickness of the sheet to be blanked. Improper clearance produces rough blanks, is hard on tools, and requires more power.

The walls of the die opening should be tapered away from the cutting edge 3 to 5 deg. to permit the blank to drop through easily. The sheet clings to punch on its up-stroke unless a stationary stripper is attached to the die or a spring stripper to the punch.

Both the sheet to be blanked and the cutting edges of the tool should be lubri-

cated. A medium-grade engine oil plus a little fatty oil diluted with kerosene is best for harder and thicker sheets. For soft alloys and tempers, dilution of the mixture is not necessary.

Where necessary to maintain a bright finish and avoid scratches, the stripper and faces of the punch and die should be covered with cloth, except at the cutting edges. Shellac is used to hold the cloth.

Combining two or more dies to take advantages of odd shapes is called "gang blanking." In "stagger" blanking, the sheet is manipulated back and forth to obtain maximum number of pieces. Blanking down one side of a stripper and up another is called "progressive" blanking.

In the aircraft industry, the Buerin, or rubber pad method, consists of placing metal over small dies that have been carefully laid out. The bottom of the ram, covered with a rubber pad, comes down; then as the rubber adjusts itself to the shape of the various dies, it blanks out the aluminum pieces.

Blanks can be cut by several other methods. Guillotine shears are used for straight cuts. Unishear is used to cut either straight or curved lines, and when sheets are thicker, the nibbler can cut to any pattern.

A hand or circular saw is satisfactory if the blade is well lubricated. Blade speeds of 5,000 fpm. for band and 10,000 fpm. for circular saws are used.

A router machine is used for cutting stacks of sheet-metal blanks. The cutter is a small diameter, high-speed, vertical milling tool, and is guided by a template clamped to the sheet.

—*Aviation*, Vol. 43, July 1944, pp. 166-167, 264, 267.

Studies on Brass Plating

Condensed from "Journal of the Electrodepositors' Technical Society"

Tests on brass plating were carried out with special reference to the effects of the various factors on the composition of the deposit and its efficiency of deposition. The copper content of the deposit tends to be raised by increased temperature and current density, and lowered by increased ammonia content of the bath, increased pH, and increased zinc concentration.

The relationships are not linear. Current efficiency is improved by high bath temperature, high ammonia concentration, high pH and metal concentration, and is lowered by increased current density.

Accumulation of ferro-cyanide in the bath has a bad effect on anode efficiency, and complicates control. The use of bare steel tanks is therefore not recommended, and drag-in of iron salts from prior pickling of steel articles should be avoided.

Three alternative plating baths are recommended, according to circumstances. Bath No. 1 is of traditional composition, and is useful for general purpose work. This bath contains in g. per 1., 30.9 copper cyanide, 7.7 zinc oxide, 60 sodium cyanide,

11 sodium bicarbonate, 3 ml. ammonia (sp. gr. 0.88).

Operating conditions are: 10.5-11.5 pH, 97 to 104 F. temp., 10 amp. per sq. ft. cathode current density, 5 amp. per sq. ft. anode current density, 60 to 75% current efficiency, approximately 70% Cu deposit composition.

Bath No. 2 is the same as Bath No. 1, except the ammonia is replaced by 10 g. per 1. of monoethanolamine, which has the advantage of non-volatility.

It is operated at 104 F., 15 to 20 amp. per sq. ft., and a pH below 12. In preparation, the pH must be adjusted to 11 before addition of the monoethanolamine.

Bath No. 3 is a high-metal-content bath with a low copper:zinc ratio, and no added ammonia. It is capable of a higher plating rate than the other two. Careful control is necessary.

It contains, in g. per 1., 21 to 35 copper cyanide, 63 to 103 zinc cyanide, 83 to 131 sodium cyanide. Operating conditions are: 10.5 to 11.5 pH, 104 to 140 F. temperature, 10-30 amp. per sq. ft. cathode current density, 5 to 10 amp. per sq. ft. anode current density, 60 to 90% current efficiency.

—S. G. Clarke, W. N. Bradshaw & E. E. Longhurst. *J. Electrodepositors' Tech. Soc.*, Vol. 19, 1944, pp. 63-89.

Painting Zinc Surfaces

Condensed from "Industrial Finishing"

In many instances the finish on items made of zinc, zinc alloys and zinc-coated metals has retained good adherence for a reasonable period of time and then completely lost its adhesion. There are three common reasons for such failure: The zinc surface is too smooth and thus offers poor adherence; the presence of zinc destroys the normal orientation of the molecules of the finish toward the metal surfaces; and the formation of a poorly-adhering compound at the interface between the zinc and the organic finish.

Weathering the zinc surface, sand-blasting, etching with acids or acidulated solvents is still used, but such methods are not satisfactory. Among the common treatments are copper sulphate immersion, selenious acid immersion, potassium permanganate-sodium hydroxide immersion, copper sulphate-ammonium hydroxide-sodium cyanide immersion and phosphate treatment. The last for galvanized iron offers an excellent surface for the adherence of paint. It consists of an immersion in a chemical solution that is maintained at an elevated temperature, followed by a cold and hot water rinse. The completion of the reaction is indicated by the discontinuation of gassing which, in general, occurs in less than one min.

The same results occur when a typical pigmented lacquer and synthetic baking enamel are applied over treated and untreated metal surfaces, with the exception that the synthetic baking enamel appears to retain its adherence for a longer period.

For baked finishes on zinc alloys, the

temperature of the bake should be limited to a maximum of 380 F., since any higher temperature will cause a change in the structure of the alloys. With zinc die castings there might be pimpling and blistering of the surface.

—H. E. Van Sielen. *Ind. Fnishing,* Vol. 20, July 1944, pp. 52-66.

Hot Galvanizing Strip Steel

Condensed from "Stahl und Eisen"

Investigations were made with steels of up to 1% carbon content to determine the influence of the latter on uniformity, thickness, adhesion and deformability of the zinc coating.

In sheets cleaned previously by sandblasting, the carbon content had no effect on formation, uniformity of thickness, and adhesion of zinc coatings. On sheets pickled only, irregular coatings formed which showed, increasing with increasing carbon content, black spots that apparently are due to the irregular attack of the pickling agent. It is being investigated if this can be prevented by some means during pickling.

The carbon content had no appreciable influence on the thickness of the hard zinc layer. The deformability in folding and deep-drawing tests became somewhat less with higher carbon contents, but this effect also was not very decided.

A higher carbon content was, as could be expected, entirely favorable for the resistance against alternating bending stresses. Previous treatment by sandblasting had a small but distinctly favorable effect.

The results with sheets show in general that a higher carbon content has no unfavorable results in hot-galvanizing, but the sheets must have a very clean metallic surface; they must, therefore, have been pickled very carefully and be free of pickling residues when dipping in the zinc bath. The best surface quality for hot-galvanizing is obtained by sandblasting.

It must be mentioned that in all annealed sheets very little or no hard zinc formation occurred. An influence of the type of galvanizing—dry or wet galvanizing—on the thickness of the hard zinc layer could not be established.

—W. Püngel. *Stahl u. Eisen,* Vol. 64, Feb. 17, 1944

Protracted Heating of Aluminum Alloys

Condensed from "Luftfahrt-Forschung"

Several aluminum alloys were investigated to find the change of their tensile strength, yield strength, elongation and Brinell hardness at room temperature after their having been subjected to the following temperatures for 40 and 340 hr., respectively: 150, 220, 270 and 320 C.

It was found that at low temperatures

the alloys RR 56 and RR 59 were superior in all properties but elongation, while at high temperatures the best results were obtained with Hy 51, which had best elongations throughout. RR 56 and RR 59 show good results even at 320 C. for 40 hr., but not as good when exposed to it for 340 hr.

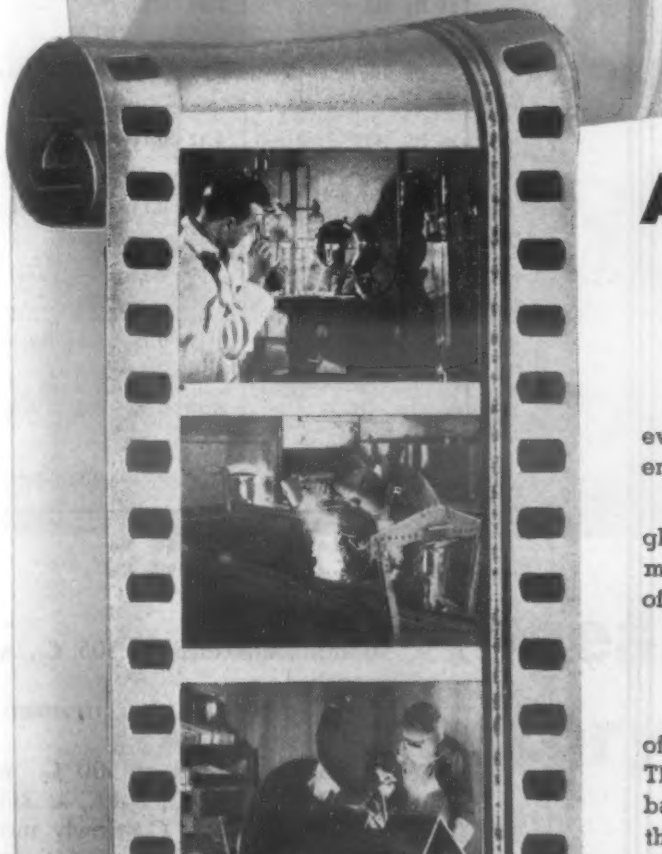
Pressed alloys in general show much higher elongation, while sand cast alloys show higher hardness, especially at high temperatures surpassed only by RR 56 and RR 59 in the two lower temperature ranges.

The analyses of the three alloys mentioned above are as follows:

	Cu	Fe	Mn	Mg	Ni	Si	Ti	Zn
RR 56	2.30	1.14	0.02	0.82	1.29	0.84	0.08	Tr.
RR 59	2.09	1.03	0.02	1.47	1.26	0.98	0.14	0.07
Hy 51	0.08	0.43	0.22	4.83	—	0.99	0.01	0.06

A total of 21 alloys was tested, eight of which were pressed and 13 sand cast. Their analyses and all results are tabulated below:

	Cu	Fe	Mn	Mg	Form
1 Duralumin W	4.03	0.30	Tr.	1.50	pressed
2 Y alloy	4.28	0.44	0.28	1.55	sand cast
3 EC 124	1.13	0.48	0.06	1.14	pressed
4 RR 56	2.30	1.14	0.02	0.82	pressed
5 RR 59	2.09	1.03	0.02	1.47	pressed
6 Hy 51	0.08	0.43	0.22	4.83	pressed
7 Hy 511	0.02	0.35	0.19	4.92	pressed
8 Hy 51	0.06	0.42	0.21	4.81	sand cast
9 Hy 511	0.01	0.50	0.14	4.92	sand cast
10 Hy 51	0.02	0.21	0.27	5.23	sand cast
11 Hy 51	0.50	0.22	0.23	5.25	sand cast
12 Hy 51	1.09	0.25	0.23	5.25	sand cast
13 Hy 511	0.03	0.28	0.19	5.35	sand cast
14 Hy 511	0.62	0.28	0.22	5.38	sand cast
15 Hy 511	1.25	0.20	0.23	5.45	sand cast
16 Hy 5112[1]	0.04	0.36	0.17	5.25	sand cast
17 Hy 5112[1]	0.60	0.36	0.17	5.31	sand cast
18 Hy 5112[1]	1.07	0.37	0.17	5.24	sand cast
19 KS 280[2]	1.68	0.59	0.87	0.17	sand cast
20 Flw. 3115.5	4.14	0.45	0.65	0.76	pressed
21 Flw. 3125.5	4.28	0.39	1.17	1.00	pressed



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	Ni	Si	Ti	Zn	Form
1 Duralumin W	1.07	0.22	0.013	Tr.	pressed
2 Y alloy	2.00	0.42	0.014	—	sand cast
3 EC 124	1.06	12.10	0.12	Tr.	pressed
4 RR 56	1.29	0.84	0.08	Tr.	pressed
5 RR 59	1.26	0.98	0.14	0.07	pressed
6 Hy 51	—	0.99	0.01	0.06	pressed
7 Hy 511	—	1.16	0.13	0.06	pressed
8 Hy 51	—	0.98	0.01	0.06	sand cast
9 Hy 511	—	1.15	0.15	0.06	sand cast
10 Hy 51	—	0.98	0.008	—	sand cast
11 Hy 51	—	0.97	0.01	—	sand cast
12 Hy 51	—	1.08	0.01	—	sand cast
13 Hy 511	—	1.09	0.15	—	sand cast
14 Hy 511	—	1.18	0.13	—	sand cast
15 Hy 511	—	1.81	0.14	—	sand cast
16 Hy 5112[1]	—	1.12	0.14	—	sand cast
17 Hy 5112[1]	—	1.11	0.14	—	sand cast
18 Hy 5112[1]	—	1.09	0.14	—	sand cast
19 KS 280[2]	1.50	21.11	0.15	0.04	sand cast
20 Flw. 3115.5	—	0.27	0.02	0.05	pressed
21 Flw. 3125.5	—	0.78	0.01	0.1	pressed

[1]Additional constituent of 0.18% Be
[2]Additional constituent of 1.19% Co

Heat treatment:

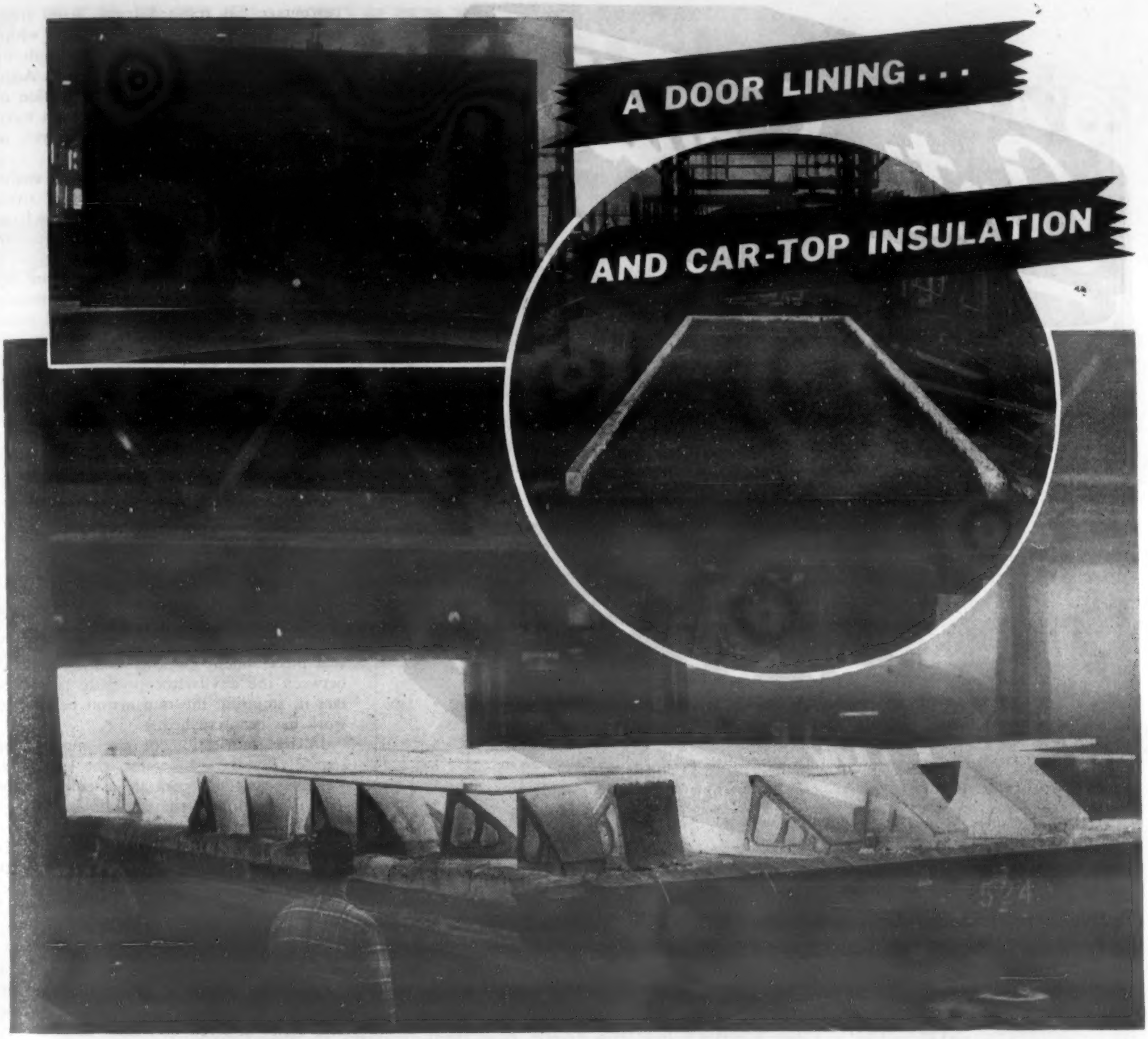
1: 50 min., annealed at 505 C., water quenched.
2: 3 hr. at 300 C. after treatment of No. 1
3: 90 min., annealed at 500 C., water quenched at 75 C., 7 hr., at 200 C.
4-5: 30 min. at 350 C., slowly increasing during 45 min. to 525 C., water quenched, 16 hr. at 170 C., water quenched
6-9: no treatment
10-18: 3 hr. at 300 C.
19: annealed at 250 C.
20-21: annealed at 500 C., water quenched

—F. Bollenrath & H. Grober. *Luftfahrt-Forsch.*, Vol. 20, No. 10, 1943, pp. 288-291.

Riveting of Aircraft Parts

Condensed from the "Iron Age"

A great saving of manpower and reduction of rivet rejections to a very small



More Annealing Furnace Work for Refractory Insulating Concrete

THE pictures above tell a story of Refractory *Insulating* Concrete that is repeated in many steel plants today.

In this heat-treating furnace both the door lining and the subhearth for the car-top are made with LUMNITE and lightweight insulating grog. The 9½ x 16-ft. door lining is cast in one piece, without joints. The Refractory *Insulating* Concrete subhearth for the 42 x 15 ft. car-top is 9 in. thick.

An important advantage of this monolithic Refractory *Insulating* Concrete lining is its resistance to the shock of frequent opening and closing of the door. It has no small pieces to fall out and cause frequent patching or premature failure. Both the jointless door lining and subhearth reduce heat loss and infiltration of air. Low conductivity and low heat storage save fuel and keep furnace temperatures up.

For information on the efficient use of LUMNITE in your plant, write The Atlas Lumnite Cement Company (United States Steel Corporation Subsidiary), Dept. M, Chrysler Building, New York 17, N. Y.

LUMNITE FOR REFRACTORY CONCRETE

percentage has resulted from "gang riveting" at the Ryan Aeronautical Co., which uses multiple riveting machines built by the General Engineering Co., Buffalo. Additional benefits include: the elimination of rivet gun marks on the surfaces, skin waviness, and swelled rivets between layers of skin.

With the aid of special handling equipment, women operators have upset rivets at the rate of 2300 per hr., and handle large assemblies, such as spars measuring up to 24 ft. long and weighing 60 lb.

The machines, type GMHR-48, are designed for heavy duty, high-speed production. They are made of welded steel plate, and are operated by a hydraulic system and controlled by a sensitive foot switch that can release power to a maximum capacity of 1000 lb. per sq. in. Pressing the left pedal of the foot switch drops the ram to give a 3½-in. free opening.

The amount the rivet head is flattened is controlled by a dial. The machine is self-compensating for changing stock thicknesses. The pressure rails or pins in a standard anvil set contact the piece being riveted and act as a gage of how much further the ram travels to the control cut-off point.

There are 10 control steps on the dial, from 0.050 to 0.150 in. height of head. If a piece should be accidentally misplaced between the anvils, the pressure rails contact it, stopping the ram action before the work has been crushed.

In the fabrication of the outer panel spar of the B-24 Liberator, the spar caps, web and spar stiffeners are assembled in a drill jig clamped tightly into place and drilled. Then the web is burred and the spar cap to which the web is fastened is preloaded with flat head rivets. The assembly is placed on the handling fixture and a few bolts are placed in the rails to hold the assembly together before the operator starts the machine.

The multiple anvils are designed to upset twelve 3/16-in. rivets at each stroke of the ram, after which the spar is moved to the next series of rivets and lines them underneath the upper anvil. It takes the operator one hr. to rivet the spar caps and the web splices, with 3,000 rivets in this spar.

Some assemblies require table equipment and others overhead monorail systems. In one section, monorail construction covers an area 60 by 60 ft., and is supported on 2½-in. pipe columns on 20 ft. centers. Standard channels, as cross members, brace this structure.

All such equipment is of light material. Thus, the monorail tracks are of 0.016 gage material, able to support 250 lb.

—J. E. Cooper. *Iron Age*, Vol. 154, Aug. 24, 1944, pp. 56-58.

Compressed Air Chucking

Condensed from "Screw Machine Engineering"

The compressed air powered chuck on today's industrial machine tool speeds up the loading and unloading of work and relieves the operator of all physical strain.

It also enables the machinist to apply all his specialized knowledge to the actual machining operation.

Compressed air operates either air-cylinder or hydraulic-cylinder chucks, and is suited to the rapid handling of light and medium work, and for holding very heavy work. To all practical purposes its action is instantaneous.

Along with many other modern compressed air tools, such as reamers, riveters, drills, and hoists, the industrial plant is today supplied with highly specialized and efficient working tools in the improved air operated equipment.

Two styles of air cylinders are in general use for chucking purposes. One is a single action air cylinder, which closes the chuck with air application and is opened by means of a spring. The other is double acting, opening and closing by air pressure.

—Educational Committee, Compressed Air Institute. *Screw Machine Engrg.*, Vol. 5, July 1944, pp. 76-77.

Silver Brazing Hints

Condensed from "The Welding Journal"

Silver brazing, or silver soldering, or hard soldering, has been used for years in the manufacture of silverware and jewelry because it makes a strong joint and the color of the base metal can be matched. Though the silver alloy is expensive by weight, the cost of the finished product is relatively low because of the small quantity needed.

Silver, copper and zinc are the chief components, the silver ranging from 10 to 80%. The melting point varies from 1200 to 1500 F., or midway between ordinary solder and a bronze welding rod. Tensile strengths run from 40,000 to 60,000 p.s.i.; ductility from 5 to over 35% in 2 in.; electrical conductivity from 14 to 77% of that of copper; and color from yellow to white.

There are eight standard grades: No. 1, used where 1600 F. will not damage the base metal; Nos. 2 and 3, used on copper, brass, bronze, etc., and on steel and dissimilar metals; Nos. 4 and 5, for all-around use; No. 6, where white color and low melting point are needed; Nos. 7 and 8, having extreme ductility, used for joining copper rods to be drawn into fine wire.

Silver brazing is best done with the oxyacetylene blowpipe. Parts to be joined must be cleaned mechanically and chemically, then coated with flux. The edges and surfaces should be smooth and tightly fitted. The merest film of brazing alloy is sufficient.

Flux dissolves any oxide formed while heating, keeps out atmospheric oxidation, and facilitates easy "tinning". Flux should be placed only on those parts where the silver is to adhere.

After fluxing, the joint is heated with a soft neutral flame, keeping the blowpipe moving in circles, with the inner cone

(Continued on page 1053)

2 in. above the surface. When the base metal has reached the melting point of the alloy, the flame is withdrawn and the end of the brazing wire touched to the surface. It will quickly melt and flow, due to capillary attraction to all parts fluxed.

—H. H. Griffith. *Welding J.*, Vol. 23, July 1944, pp. 624-626.

Age Hardening of Aluminum Alloys

Condensed from "Zeitschrift für Metallkunde"

The precipitation-hardening of aluminum-copper-manganese alloys is very strongly influenced by the composition during the first hours after quenching, and impurities of Si, Fe and, especially, Mn have another important effect. The whole hardening process was, therefore, studied by hardness-time curves, taking into account the duration of the homogenization annealing.

It was found that an increase of the silicon content increases the precipitation-hardening velocity as compared with the "pure" alloy if the magnesium content is large; for small magnesium contents, the precipitation-hardening velocity is reduced. The addition or increase of the iron and manganese content reduce, in general, the precipitation-hardening velocity, more so at low than at simultaneously high silicon content.

The lowest precipitation-hardening velocities are obtained at low silicon content and increased iron and manganese values. Increasing the duration of homogenization annealing increases, in general, the precipitation velocity.

—W. Mannchen. *Z. Metallkunde*, Vol. 35, Apr. 1943, pp. 93-96.

Atomic Hydrogen Arc Welding

Condensed from "Western Machinery and Steel World"

Early use was made of the atomic hydrogen arc welding process at Ryan Aeronautical Co., where it was discovered to have advantages over oxyacetylene welding for light gages of stainless steel. Use of excess acetylene in the latter method, in connection with the longer time required, resulted in carbon pick-up and loss of the stabilizing elements of columbium and titanium. The use of hydrogen provides a reducing atmosphere, and heat transfer is so rapid that the time at welding temperature is shortened.

High corrosion resistance must be maintained in stainless steel parts—exhaust collectors, heat exchangers, etc.—that are subject to high service temperatures. Curiously, the ductility and corrosion resistance of the 18-8 steels are usually closely related.

Early difficulties with the process arose from operators having trouble controlling speed of welding. Too slow a speed often

resulted in burning through, while too fast welding resulted in severe shrinkage of the weld over its length, with a series of cracks across the weld.

The "silent arc" obtained with the electrodes close together permitted a finer control on thin gages of metal, while the "singing arc" often forced such rapid welding that cracks would develop. "Wormholes" almost in the center of the weld also resulted from too rapid welding.

Techniques now in use demand a slower welding speed than formerly, but the process is still a little more than twice as fast as oxyacetylene welding. Use of the "silent arc" has become standard because of the finer control obtainable.

Higher hydrogen pressures and higher current are used in tacking. Adjusting the tungsten electrodes to permit rotating the arc fan to almost any angle has been found helpful in welding joints.

Atomic hydrogen welding is being used successfully in the welding of low-carbon steel sheet of thin gage. A narrower weld bead is obtained, along with adequate penetration.

The cost of atomic hydrogen welding is lower than that of oxyacetylene welding because of the greater amount of welding that can be completed in an eight-hour day. About one-third of a cylinder of hydrogen per operator is used daily, and the electrode cost is about 20 cents. It makes the use of flux unnecessary in many operations.

—William J. Van den Akker. *Western Machinery & Steel World*, Vol. 35, July 1944, pp. 276-278.

Zinc Dust in Plating Solutions

Condensed from "Metal Finishing"

To produce acceptable zinc deposits, alkaline zinc plating solutions must be free from heavy metal impurities. Heavy metal impurities, such as cadmium, lead and copper, are codeposited with zinc, and alter both the appearance and the physical properties of the deposit.

Some impurities cause smutty, streaked deposits. Even though of sound appearance, deposits containing heavy metal impurities do not have as high a protective value as pure zinc. Furthermore, it has been found that subsequent finishes, such as Cronak or Bonderizing, are difficult to apply to impure deposits.

The experiments reported in this paper show that when a solution has a copper concentration of 0.0075 oz. per gal., the deposit is satisfactory. When the concentration is in the range of 0.01 to 0.03 oz. per gal., the deposits are barely acceptable if bright-dipped in ½% nitric acid solution. At higher concentrations of copper, the deposits are not acceptable, ranging from dark matte to black.

The presence of heavy metal impurities in the solution causes an accelerated attack on the zinc anodes, resulting in build-up of zinc in the bath. This necessitates the wasteful procedure of discarding a portion

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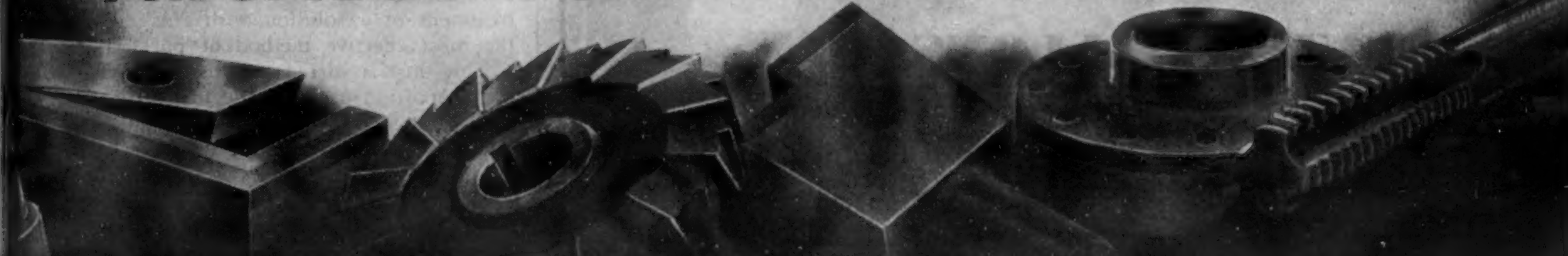

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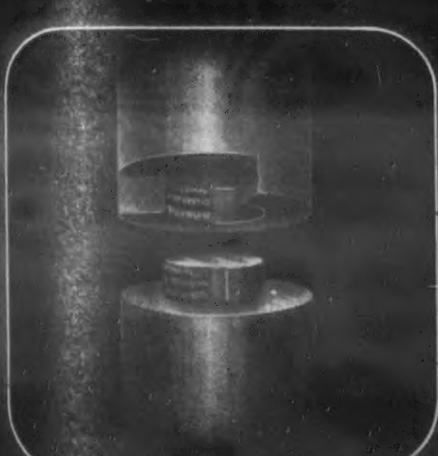

The new Arcaloy Tool Steel arc-welding electrodes provide tremendous possibilities in repairing and rebuilding tools and dies, and also in the composite fabrication of new dies needed for retooling.

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ARCALOY HOT-WORK Electrodes are used to repair typical Hot-work steels and also to fabricate composite units where Hot-work characteristics are wanted on working areas.

ARCALOY WATER-HARDENING Electrodes are used for repairing all water-hardening tool alloys.

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of the bath to readjust the zinc concentration.

Various treatments have been proposed for the elimination of heavy metal impurities in alkaline zinc solutions. In making a new solution, a purification treatment is always desirable. It has been found that treatment of a solution with zinc dust is the most effective method of purification.

Zinc dust is stirred into the solution in the proportion of from one to five lb. for each 100 gal., for a time of 20 min. to two hrs., depending on the degree of contamination, and then removed by filtering.

Heavy metal impurities are precipitated on the surface of the zinc dust particles and a corresponding amount of zinc goes into solution. A standard grade of zinc dust, 325 mesh, is suitable.

In case a solution is heavily contaminated, *e.g.*, with as much as 0.25 oz. per gal. of copper, the most effective way of removing the bulk of the copper is by electrolysis with dummy cathodes at a low current density, *e.g.*, two amp. per sq. ft. When the copper concentration has been reduced in this way to about 0.04 oz. per gal., electrolysis is no longer effective, and the zinc dust treatment is applied to further reduce the copper concentration to below 0.0005 oz. per gal.

—Myron Diggin. *Metal Finishing*, Vol. 42, June 1944, p. 344.

Drawing Temperature Effects

Condensed from "Stahl und Eisen"

The change in mechanical properties of rod sections of 60- and 30-mm. diam. as dependent on drawing temperature was investigated in two plain and 10 alloy steels with manganese, silicon, chromium, and/or vanadium. Hardness measurements at the surface and over the section, tensile tests, and notch-impact tests were used.

The hardness measurements indicated that the through-hardenability must be limited to certain drawing stages and, thus, certain ranges of mechanical strength. For the same drawing temperature, the tensile strength of the unalloyed or manganese-bearing steels is less than that of the chromium alloy steels. The highest elastic limit ratio lies at the highest tensile strength and, therefore, lowest drawing temperature.

No distinct superiority can be found in the alloy steels as regards the reduction of area at fracture; the latter decreases much more than elongation at fracture towards higher values of tensile strength. The notch impact toughness was best in the steel with 2.5% Cr and 0.2% V.

The drop of notch-impact toughness with increasing tensile strength takes place particularly between 100 and 115 kg. per sq. mm. tensile strength (142,000 and 164,000 p.s.i.). The differences of mechanical properties within the rods (from edge to core) are in some steels quite considerable.

—A. Krisch. *Stahl u. Eisen*, Vol. 64, Feb. 17, 1944, pp. 105-110.

Materials and Engineering Design

Engineering Properties of Metals and Alloys • Resistance to Corrosion, Wear, Fatigue, Creep, etc. • Engineering Design Problems of Specific Industries and Products • Selection of Metals, Metal-Forms and Fabricating Methods • Non-Metallics in the Metal Industries • Applications of Individual Materials • Conservation and Substitution

CONTENTS

Sheet Metal in Compression

Condensed from "Automotive and Aviation Industries"

Each testing laboratory seems to have its own method of determining the compression properties of sheet metal, and at times there is little correlation among the results so obtained. Consolidated Vultee has developed improved methods after finding that there was no method of obtaining the compression properties of thin sheet metal accurately and rapidly.

At first, the block or stringer back-to-back test method was used to determine the yield point in compression of aluminum alloys. The stringer under test was cut into sections 3 to 5 in. long, which were riveted together in pairs and the ends were ground flat and parallel. These coupons were then processed in the same manner as the basic specimen.

Later, a simplification of the N. A. C. A. "pack" and Vega "roller" methods was developed. The 3 by 1 in. coupons are blanked from sheet and gang milled or ground flat and parallel in groups of ten or twenty. The specimen consists of the test coupon with two projecting tabs to which the extensometer is attached, sandwiched between wood or metal side plates.

The compression deformation is determined by (1) 1000:1 Huggenberger extensometer; (2) Celstrain gages (Convair electric wire strain gages) or (3) by any standard extensometer. An experienced operator can make a sandwich test within 8 to 10 min. after the coupons have been shaped and the ends ground flat.

A comparison of the two methods indicates that both give equally accurate results when properly made, but the stringer back-to-back method takes several times as long as the sandwich method. Either is several times as rapid as the Vega "roller" or the N. A. C. A. "pack" method. Use of an autographic stress strain recorder on the sandwich coupons gives a permanent record of each compression test.

—K. R. Jackman. *Automotive & Aviation Inds.*, Vol. 90, June 1, 1944, pp. 36-38, 82.

Rationalizing Insulation Dimensions

Condensed from "Mechanical Engineering"

Thermal insulation has, within recent years, become a dimensional product, and there are advantages in having a simple and definite scheme with which to design and order pipe insulation. The author has made a study of insulation dimensional characteristics for this purpose. The main thought was to reduce the number of sizes, thicknesses and types of insulants to a minimum, and to co-ordinate different types so that a more complete interchange might be accomplished.

At recent meetings of the author and others similarly interested, it was decided that any change at the present time might

conflict with war production. However, with intensive study it is hoped to have a satisfactory conclusion available for post-war production.

One of the most difficult phases of handling insulation is the endeavor to maintain an adequate but minimum stock. Odd sizes often require an excessive amount of space.

Tables representing materials now manufactured have been compiled. A comparison of these tables with the proposed schedule revealed that a reduction of approximately 78% could be effected in the number of pieces of pipe insulation required. At present, out of 614 pieces now available, a thickness of only 4 in. is obtainable.

The proposed schedule, with only 135 pieces, provides all pipe sizes and any thickness within the scheduled range. Complete interchange of materials is possible. The key to the simplification lies in the provision for outside dimensions of all pipe insulation to nest in some larger size.

The insulation may be manufactured up to any desired thickness by cementing together a sufficient number of successively larger sections, or in one single layer. This schedule will provide uniform dimensions for all manufacturers, and eliminate the present odd sizes.

—Ray Thomas. *Mech. Engrg.*, Vol. 66, July 1944, pp. 480-481.

Steels for Low Temperatures

Condensed from "Stahl und Eisen"

While elastic limit and tensile strength increase with decreasing temperatures, elongation at fracture and reduction of area behave irregularly at decreasing temperature, and instead of deformation fracture after strong deformation with a lamellar appearance, the separation fracture with granular appearance takes place after slight deformation.

The tendency to separation fracture, in which the crystals split in crystallographically preferred planes before a stronger deformation takes place, increases strongly with decreasing temperature, and can be considered as a characteristic property of the alpha-iron, which forms the ferritic basic mass of the annealed and hardened steel and has a cubic-space-centered atomic lattice.

The same phenomenon takes place in zinc with a hexagonal lattice, but only to a much lesser degree in copper and nickel, both of which have a cubic-face-centered lattice. The testing of steels for use at low temperatures is, therefore, preponderantly a test for the tendency to separation fracture; the notch-impact test also greatly decreases the notch-impact-toughness.

The test result depends largely on the selection of the testing conditions, and particularly the shape of the specimen. The usual DVM test with 55 by 10 by 10 mm. with 3-mm. deep notch of 2-mm. diam. is considered too hard; the Bennek test with 55 by 10 by 8 mm. and 4-mm. deep notch of 8-mm. diam. is considered to be more apt to give reliable results.

In the heat treatment of such steels, all means should be used that reduce the decrease of notch-impact strength with decreasing temperatures, especially composition, and the grain should be as fine as possible. These steels should be deoxidized with a strong deoxidizer, *e.g.* aluminum.

The demand of sufficient notch-impact toughness, even with the DVM test, at the temperature of liquid air can be met only by austenitic steels, both austenitic chromium-manganese and manganese steels, and austenitic chromium-nickel and nickel steels.

In the extensive discussion of the paper, it was particularly emphasized that a higher aluminum content, exceeding considerably that necessary to prevent aging, is of utmost importance in producing a cold-notch-tough steel. Contents of 0.2 and more improve notch-impact toughness considerably, at least to —80 C.

—H. J. Wiester. *Stahl u. Eisen*, Vol. 63, Jan. 21, 1943, pp. 41-47; Jan. 28, pp. 64-74.

Strains in Riveted Joints

Condensed from "Aero Digest"

Tests were made to supplement the meager available data on the effect of oversized rivet holes and stressed rivets on the strength of joints.

In the first part of the work, a rivet in an oversized or elongated rivet hole was tested tandem with a rivet in a correct hole to measure simultaneously the elasticity and the strength of the joint. An increase in the elasticity of the joint should be revealed by the loss in strength.

A17ST ⅛ in. diam. rivets were used with ⅛, 5/32, 3/16, 5/32 by ⅛, and 3/16 by ⅛ in. holes. Both brazier head and countersunk head rivets were tested. Sheet gages varied from 0.020 to 0.064 in. All tests gave a failing load considerably above the minimum allowable.

The results on the 0.020- and 0.025-in. brazier head specimens were not very consistent, but this could not be attributed directly to the hole size, since almost all the failures were due to pulling one or both rivet heads through the plates.

In all but one case, both types of rivets in the heavier sheets gave stronger joints with the enlarged holes than with the proper holes. This indicates that the rivets completely filled the holes, thus adding to the shear strength. The countersunk rivets gave results closely paralleling those with the brazier head rivets.

Therefore, oversized holes do not reduce the strength of the riveted joint if (1) the effect of the reduction in area of the sheet does not weaken the joint, and (2) the oversized holes are not more than 50% larger than the rivet diameter if both holes are the same size, or not more than 25% larger if the holes are different. It makes no difference whether the enlarged hole is round or elongated.

Since most enlarged holes in practice come within the above limits, it is not necessary to use extra long rivets to make certain that there is enough metal to fill up the enlarged holes.

Countersunk rivets that show a wrinkling of the paint around the edge of the head

BECAUSE the name Acme Pattern & Tool Company, Inc. no longer adequately describes the scope of our operations, we are changing our corporate name to Acme Aluminum Alloys, Inc.

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and possibly a little bare metal are commonly called "stressed." It would be difficult if not impossible to identify such rivets if unpainted. Painted test pieces were pulled in an attempt to evaluate the actual stresses.

Strain and permanent set after release of the load were measured. The rivet must have a very considerable load applied to it before it appears "stressed," but it still has a long way to go before complete failure.

The paint wrinkles and even the first appearance of bare metal are found at permanent sets on the order of 0.2% permanent set in 2 in., which would not be considered unsatisfactory in sheet. However, dishing of the rivet heads usually occurs when the strains become unacceptably high. Therefore, rivets showing a slight wrinkling of the paint and even a trace of metal around the edge of the head should not be regarded with undue alarm.

—J. A. Chamberlin. *Aero Digest*, Vol. 46, July 1, 1944, pp. 101-102.

Light Alloy Engine Castings

Condensed from "Diesel Engine Users' Association"

The design of heavy-oil engines tends towards lighter units through higher speed. The three main advantages in the use of aluminum alloys are their specific gravity (2.6 to 3.0), their thermal conductivity (0.52 to 0.54 C.G.S. units), and their physical properties, which are adequate for stressed parts operating at high temperatures; while the three main disadvantages are cost, which is inherently higher than most other metals, a low modulus (10,000,000 p.s.i.), and a thermal expansion double that of iron.

For aluminum alloy pistons, the heat-treatment specified is the final main factor which affects clearances, and all of the alloys now used for Diesel engine pistons are amenable to improvement by heat-treatment. The ideal to aim at in heat-treating a piston casting or forging is to remove all residual stress and to acquire as closely as possible in advance those mechanical properties it will certainly attain in time in service.

Whether a light alloy piston should be cast or forged is a matter of personal choice, for the basis of design is the same, and the only two points that may affect long service are wear of rings and grooves and wear of skirts. The use of a forging, however, limits design to the simplest. Aluminum alloys suggested for pistons include the cast alloys Y, R R 53, Ceralumin C and Loex, and the forged alloys R R 59 and Ceralumin 22.

In aluminum alloy combustion heads, thermal conductivity is the main property required in order to avoid hot-spots and resultant cracks, while relative freedom from scaling is also a suitable factor in the choice of a suitable alloy. Two groups of alloys are used for this purpose, one based on silicon but stiffened with copper, the other based on copper but made easier to cast with the aid of silicon.

The application of aluminum alloys to crankcases is of considerable importance from the point of view of reduction of deadweight, and where the cylinder block is not combined with the crankcase in a single casting, similar alloys to those used for cylinder heads may be used for this latter component.

Other castings made in light alloys are those for oil sumps, crankcase doors, valve covers, etc., and alloys suggested for their use are those with a good corrosion resistance.

High-duty parts, such as bearing caps, function suitably when made of die-cast or drop-forged high-strength light alloys. Alloys suitable for bearing shells are duralumin, certain R R alloys, or alloys specially developed for such a purpose. Light alloy forgings are also suitable for connecting rods in which the saving of inertia forces is of importance.

—G. Mortimer & J. G. Paige. *Diesel Engine Users' Assn.*, 1944, S. 175, pp. 1-19.

Creep-Resisting Zinc Alloys

Condensed from "Zeitschrift für Metallkunde"

The creep behavior of zinc which (in Germany) has in many fields replaced aluminum were thoroughly investigated, as mechanical difficulties were encountered with wires in clamps where the metal began to flow under the clamping pressure. The effect of some metals on the creep behavior of 99.99% pure zinc and the properties of a zinc-iron alloy with about 0.15% Fe was determined with regard to use as electrical conductor material. The experimental alloys were:

Alloying Element	Solubility in Zinc	Added Amount %	Heterogeneous Phase
Arsenic		0.039[1]	As_2Zn_3 with about 44% As
Calcium		0.025[1]	$CaZn_{10}$ with about 6% Ca
Cobalt	0.02	(a) 0.035 (b) 0.20	E with 6% Co
Chromium	0.1	(a) 0.007 (b) 0.19	B with 7% Cr
Iron	0.03	(a) 0.017 (b) 0.17	E with 6% Fe
Magnesium	0.06	(a) 0.008 (b) 0.02 (c) 0.11	$MgZn_5$ with 7% Mg.

[1] *Alloys with about 0.2% addition could not be hot-deformed, and no wire was drawn.*

The tests showed that the creep strength of pure zinc is increased considerably by additions of chromium, cobalt and iron, especially in the range of the solubility in zinc. The alloy of zinc with about 0.15% Fe was found particularly suitable for electrical installations, and superior to zinc-aluminum wire. As regards the corrosion behavior and intercrystalline corrosion, the former is much better.

Designing Molded Plastics Parts: CHEMICAL RESISTANCE

From the engineering files of One Plastics Avenue

Many applications of plastics are specified to take advantage of the chemical resistance of plastics. The degree of resistance is usually evaluated by the change in weight, dimensions, and surface appearance, or the loss of strength which the plastic shows when immersed in the chemical at a given temperature and for a given time.

Courtesy of E. I. Dupont de Nemours & Co.

Plastics is used for this rayon spinning bucket because it gives good acid resistance and light weight making the bucket easy to balance.

The various reagents which are commonly used are most conveniently grouped as shown in the chart below. The effect which they have on the plastic is measured by describing its appearance or condition after exposure. Unless applications duplicate these tests exactly, the table should be used only as a guide to pick the most likely materials, and actual service tests should be made.

Courtesy of Galloway Co., Inc.

Milk handling equipment such as these cream separator skimming disks makes use of the chemical resistance of plastics. These disks have good resistance to lactic acid and the corrosive cleaning solutions that are used in cleaning dairy equipment.

CHEMICAL RESISTANCE AT 25° C°

KEY R — SURFACE ROUGHENED; D — DISSOLVED; N — NO EFFECT; S — SOFTENED; L — DELAMINATED; Z — CRAZED

	Phenolic	Cast Phenolic	Laminated Phenolic	Urea	Vinyl Chl. Acetate	Metha-crylate	Styrene	Cel. Nitrate	Cel. Acetate
30% Sulfuric Acid	R	N	S	R	N	N	N	N	Z
10% Nitric Acid	R	N	S	R	N	N	N	N	D
10% Sodium Hydroxide	D	D	L	N	N	N	N	Z	D
1% Sodium Hydroxide	R	D	S	N	N	N	N	Z	R
10% Sodium Chloride	N	N	S	N	N	N	N	N	N
Distilled Water	N	N	N	N	N	N	N	N	N
95% Ethyl Alcohol	N	N	N	N	N	R	N	D	D
Acetone	N	S	R	N	D	D	D	D	D
Carbon Tetrachloride	N	N	N	N	N	R	D	N	N
Gasoline	N	N	N	N	N	N	D	N	N

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While the bending number of the latter is reduced 96% after 14 days in the water vapor test, and the surface layers are entirely disintegrated, the reduction was only about 30% in zinc-iron wires without an indication of intercrystalline disintegration.

The tensile strength of pure zinc is 14.4 kg. per sq. mm. (20,300 p.s.i.); an addition of 0.19% Cr increases it to 21.2 (30,100 p.s.i.); of 0.17% Fe to 17.1 (24,300 p.s.i.); of 0.008% Mg to 40 (56,900 p.s.i.); of 0.11% Mg to 45 kg. per sq. mm. (64,000 p.s.i.), with practically the same electric conductivity of around 16.5 ohm per m. per sq. mm. The elongations at fracture of these wires are, in %, 50, 45, 25, 5 and 2, respectively.

—R. Reinbach. *Z. Metallkunde*, Vol. 35, Apr. 1943, pp. 99-103.

Aluminum Bronze in Marine Use

Condensed from "Shipbuilder and Marine Engine-Builder"

In recent years aluminum bronze has found its way into the marine industry principally due to its excellent anti-corrosion properties, to which is added high strength hardness and resistance to wear. The corrosion rate of aluminum bronze (85.5 Cu, 10.6 Al, 3.1% Fe) of 2.5 mgm. per sq. dm. per day compares favorably with that of a gunmetal (85 Cu, 9.1 Sn, 3.6 Pb, 2.3% Zn) of 7.5 mgm. per sq. dm. per day, both alloys being tested in sea-water.

In relation to impingement attack and cavitation erosion, aluminum bronzes have very satisfactory properties and condenser tubes of aluminum bronze, containing up to 7.0% Al, together with a proportion of nickel, have been used satisfactorily in marine and shore power installations in which both those conditions exist.

In addition to high tensile strength and a fair ductility, aluminum bronze (12% Al) has a Brinell hardness of 75 in its unworked normalized condition, and this hardness is increased as the quenching temperature is increased as shown in the following table:

Quenching temp., F.	750	930	1110	1290	1470
Brinell hardness	155	140	125	165	200

As regards resistance to wear, the addition of a slight amount of lead to aluminum bronze improves this property as well as its general workability. Such alloys are extensively used in gearwheels and worm nuts, and in parts in which high compressive loads may occur in association with indifferent lubricating conditions.

Many important fittings in the salt-water cooling circuit of marine power units have been made from aluminum bronze, including centrifugal pumps (93.5 Cu, 6.5% Al) branch pipes, and sluice valve bodies (88 Cu, 9 Al, 3% Fe) in the hydraulic circuit. High tensile valve bodies usually contain 80 Cu, 10 Al, 5 Ni and 5% Fe.

Aluminum bronzes have also been used successfully for stern-tube bearings where strength and hardness are required, and for many miscellaneous fittings such as shackles, eyeplates and bolts. In small speed-boats, in which supercharged high-output engines are installed, cast aluminum-bronze cylinder heads have been used with success, and for marine propellers, particularly in small high-powered marine craft, 7% aluminum bronze alloys having fairly large additions of iron, and slight additions of nickel and manganese give satisfactory results on account of their slightly better corrosion-fatigue properties compared with most copper alloys.

—R. A. Collacott. *Shipbuilder & Marine Engine-Builder*, Vol. 51, June 1944, pp. 242-245.

Aluminum Alloys Containing Cerium

Condensed from "Novosti tekhniki"

Experiments were conducted to determine the effect on the properties of aluminum alloys by the addition of small amounts of cerium. Studies were made with secondary aluminum-alloys containing 4 to 12% Cu with a high amount of impurities: 0.8 to 3.3 Fe, 0.25 to 1.5 Si, 0.3 to 1.5% Zn, and 1/10% Pb, Mn, Mg.

A study was also made of an alloy containing a small amount of copper (less than 2%) with an increased amount of silicon—7.6%.

Cerium was applied, not in its pure state but in the form of "mix-metal," metal alloys belonging to the rare earth group of metals (cerium, lanthanium, praseodymium, neodymium, terbium, samarium and europium), with iron. The "mix-metal" used was a coarse grained material.

According to the iron content (4 to 9%), it was sufficiently pure. The amount of cerium in "mix-metal" is usually 55 to 65%, the rest, excluding iron, being other rare earth metals. All these metals in the study were considered with cerium so that in the detailed explanation of the term "cerium" all these metals are included. This is permissible, since well-known diagrams showing properties of aluminum alloys of the rare earth group are analogous to the diagrams showing properties of the aluminum-cerium system.

In the same manner, the behavior of these metals in aluminum alloys is analogous to the behavior of cerium in them. On the other hand, maintaining cerium in "mix-metal" becomes most important.

Adding the Cerium

Production and separation of cerium from other metals of the rare-earth type is very complex and uneconomical. The experiments showed that it is unnecessary, and that "mix-metal" with a possibility of lower iron content can be used instead of the pure cerium.

The content of cerium in this experiment shifted from 0.1 to 1.0%. To study alloys with a higher cerium content was inadvisable inasmuch as introducing larger quantities of this element would greatly increase the specific gravity of alloys (specific gravity of cerium is 6.8) and greatly increase its cost.

Cerium was introduced into alloys in the

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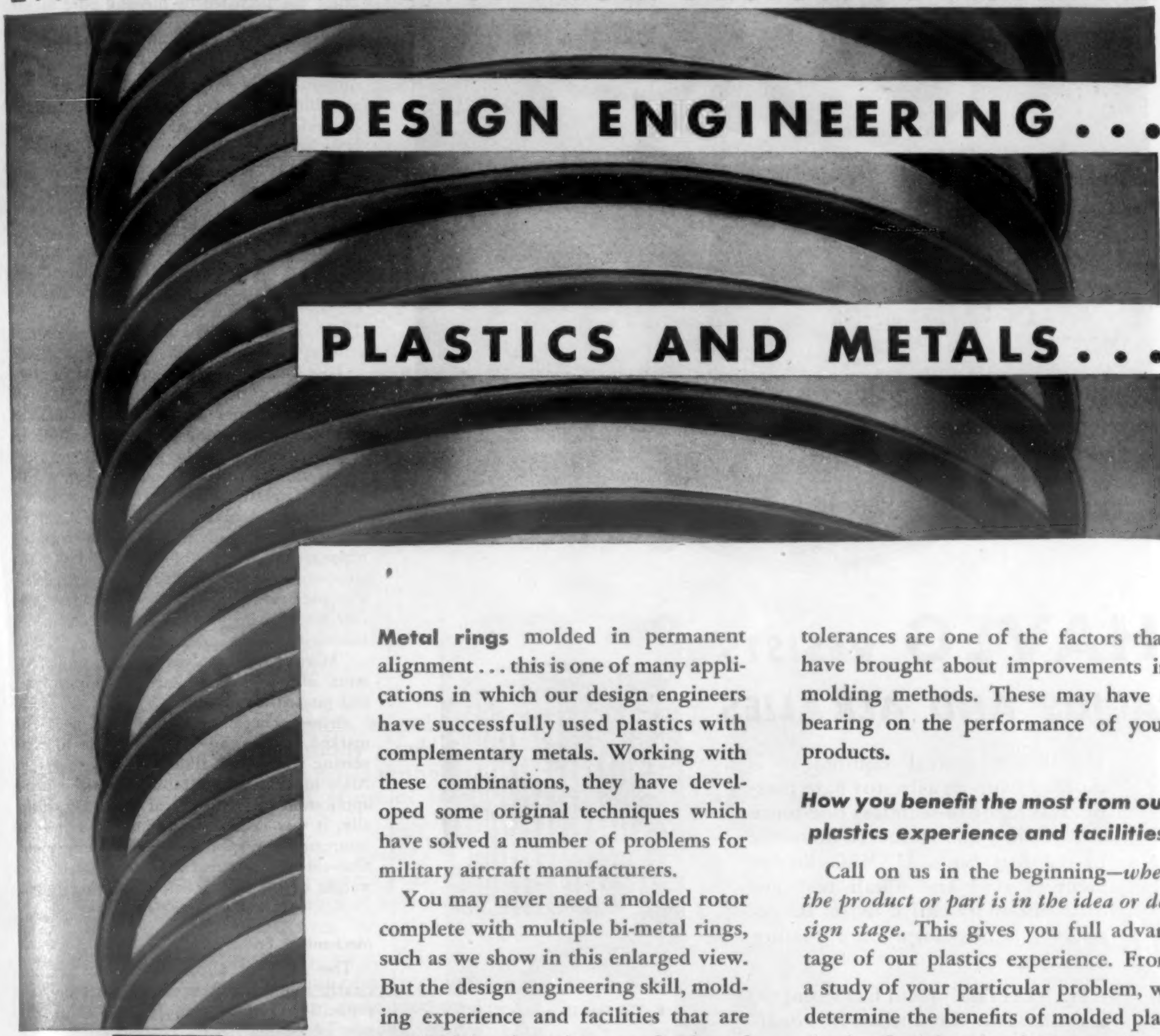

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form of an aluminum-cerium alloy. The latter was prepared by melting pure aluminum with "mix-metal." The alloy was calculated to contain approximately 9% Ce. According to the experiments, eutectic aluminum-cerium contains 8.9% Ce. and has a melting point of 637 C. The smelting can be performed in an ordinary graphite crucible heated in electric ovens or oil furnaces.

"Mix-metal" dissolves easily and quickly in molten aluminum. However, it is necessary to note that in the aluminum-cerium system there are several inter-metal combinations (*i.e.* Al_4Ce, Al_2Ce), having a melting point above 800 C. When that occurs, they (the combinations) would not dissolve but settle on the bottom of the crucible. This can be avoided by heating the aluminum at 900 to 1000 C.

Loss of metal is very small if accurately worked out (from 0.5 to 1.5%); loss of cerium in fumes fluctuates from 0.2 to 1.5%. To reduce the loss, it is possible to apply a protective slag, of a mixture of potassium chloride and sodium in equimolecular relation.

The aluminum melts under the layer of slag and is heated quickly to the needed temperature. Chunks of "mix-metal" (well-cleaned of the oil in which they are generally preserved), become submerged in the crucible and held down to the bottom by porcelain, iron or carbon rods.

"Mix-metal" dissolves quickly, and contents of the crucible are quickly mixed and poured into basins.

In preparing alloys, there is no need for marked overheating of metals prior to converting them into aluminum-cerium alloy. Alloy melting usually took place without the application of any kind of flux. Occasionally, it was necessary to clean off oxidized compounds by applying small quantities of zinc chloride (approximately 0.2% of the weight of the alloy) before pouring it off.

Mechanical Properties

The study of alloys containing cerium clearly indicated a beneficial effect on the properties of aluminum alloys by the addition of cerium. After corresponding heat treatment, there was a constant improvement of mechanical properties of aluminum alloys.

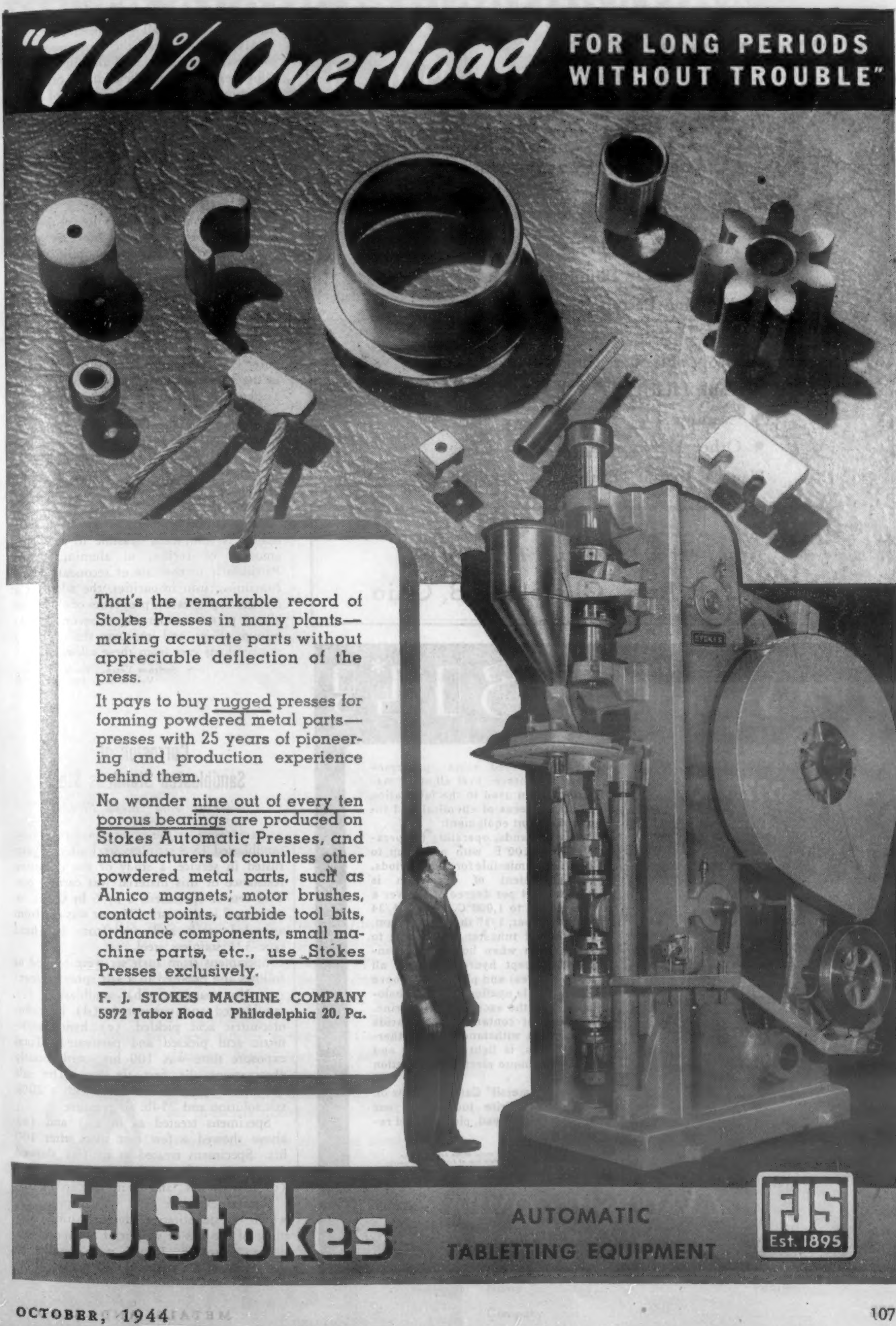
For aluminum-copper alloys the following heat treatment was applied: tempered for 4 to 4.5 hr. at 500 C., hardened in cold water and artificially aged at 175 C.; period of duration at 175 C. fluctuated between 4 to 8 hr.

Maximum improvement in mechanical properties of alloys was observed by the addition of 0.3 to 0.35% Ce. This showed a higher tensile strength of 20 to 30% and a hardness test, according to Brinell, 12 to 20% higher than alloys containing no cerium. Other samples showed an increased elongation of more than 15%.

Particularly notable was the increased elongation of several samples of silumin-alloy (containing less than 2% Cu and 7.6% Si); in other samples it rose from 30 to 50%.

Introduction of cerium in quantities less than 0.3% also showed improvement, but with corresponding less effect. Addition of cerium in amounts over 0.4% proved

(Continued on page 1078)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to be unnecessary, and even showed a negative effect on the alloy properties.

Also notable was the improved effect on the casting qualities of aluminum-copper alloys resulting from the addition of cerium. Experiments with casting made of secondary aluminum alloy without cerium showed piston rejects amounting to 16.6%, as compared with piston rejects, cast from alloy containing 0.36% Ce, amounting to 8.9%.

Furthermore, pistons without cerium were rejected (67%) primarily for cracking (for reasons attributed to alloy properties) and 33% for blow holes; however, piston rejects cast from alloys containing cerium, rejected for bubbles only, were largely due to the work of the casting shop. Rejects for cracking in this case was 0.

Metallographic experiments indicated that alloys containing cerium have a finer-grained, more even microstructure. The latter is also responsible for the diminishing of the 3rd component eutectic of Al-X phase (often seen in the slide in the form of so-called "Chinese script").

The microstructure has a finer grain than alloys not containing cerium. This beneficial influence may be explained by the fact that cerium softens the iron-silicium phase—constituting phase X in the alloy structure.

The foregoing permits the conclusion that it is completely feasible to add small amounts of cerium to aluminum-alloys. Particularly in the case of secondary alloys, containing iron impurities, the addition of cerium improves the properties of aluminum alloys, permits wider use of secondary aluminum alloys, and improves the quality of the products cast from these alloys.

—S. Smirnov-Verin. *Novosti tekhniki*, Vol. 9, Dec. 1940, pp. 20-21.

Corrosion of Sandblasted Stainless Steel

Condensed from "Metal Finishing"

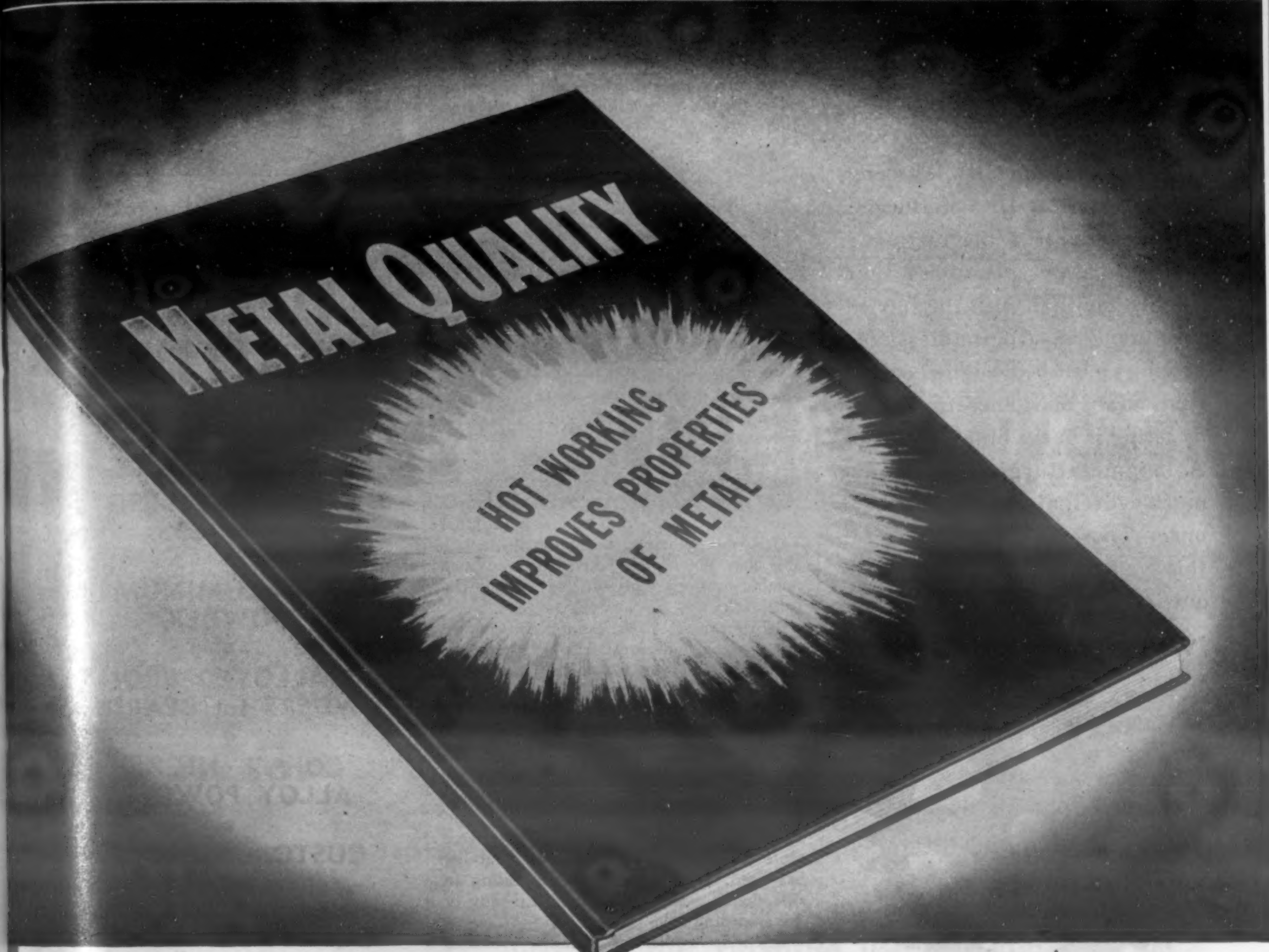
As a result of the observation that some sandblasted 18-8 stainless steel aircraft parts rusted in service, a study of the corrosion resistance of this material was carried out. Two sets of specimens 6 by 6 by 0.031 in. were used in the tests. One set was cut from annealed stock and one from half-hard type 321 stainless steel.

Specimens from each set were treated as follows and exposed in a salt spray cabinet: (a) No treatment, (b) sandblasted, (c) sandblasted and passivated, (d) hydrofluoric-nitric acid pickled, (e) hydrofluoric-nitric acid pickled and passivated. Total exposure time was 100 hrs., with hourly observations the first six hrs. The salt spray was operated at 95 F., with a 20% salt solution and 25-lb. air pressure.

Specimens treated as in (a) and (e) above showed a few rust spots after 100 hrs. Specimens treated as in (b) showed rust in one hr., specimens treated as in (c) in four hrs., and as in (d) in 24 hrs.

Similar exposure tests were repeated in which a quantitative determination was made of the loss of weight of the specimens due to corrosion. Results were parallel to the above.

How to avoid misestimating the qualities required to meet a specific service condition



This new booklet on Metal Quality will help you to obtain the exact qualities needed to meet a specific service requirement. How you utilize metal quality to insure the *dependable performance of operating mechanisms,* under a wide variety of operating conditions, will determine your progress under peacetime competitive conditions. Metal quality can be developed to the exact degree required to meet a specific service condition, and this booklet presents many examples that prove it.

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Thus, the annealed sandblasted sheets (specimens b) lost from 0.0041 to 0.0071 gms. while the specimens treated as in (e) lost from 0.0001 to 0.0005 gms. The sandblasted-passivated specimens lost from 0.0025 to 0.0029 gms.

In all cases the loss of weight by corrosion was considerably greater for the half-hard than for the annealed specimens.

The results of these tests definitely show that sandblasting does promote or accelerate corrosion of this type of stainless steel, even though passivation follows the sandblasting.

—F. A. Truden. *Metal Finishing*, Vol. 42, June 1944, pp. 335-337.

Future Steels

Condensed from "Machine Design"

Important wartime developments have been along the following lines: Fatigue endurance, heat treatment, castings, welding, alloy evaluation, hardenability, special additive agents, and N.E. steels.

We have had to revise some previous conceptions. Thus, we now learn that some parts need little or no toughness in the steel. Again, contrary to an idea held rather widely, the highest hardenability steel available may not be the best as demonstrated notably by Ford, Chrysler and Timken-Detroit Axle.

However, all parts cannot be handled this way, as some must really be hardened throughout. Through-hardened parts having stress raisers, or subject to corrosion, can sometimes be improved in fatigue resistance by going in the opposite direction.

Shot peening may eliminate the need for expensive surface finishing, and the roughened surface produced by shot peening may better retain the lubricant. Principles of annealing have been postulated more precisely than before. Machinability has been improved by cycle annealing in axle shafts, gears, etc. Carbon nitriding or dry cyaniding have progressed.

Scientific studies of foundry problems have taught much about steel melting and deoxidation, flow of molten metals and cooling phenomena. Greater use of X-ray and gamma-ray will take place after the war, but jobbing foundries may find competition severe in the more scientific age.

In welding, two outstanding developments are spot and arc welding of armor and other highly stressed parts, previously considered unweldable. Flame cutting of steel has so increased in accuracy that many intricate parts are cut so nicely that no subsequent machining is needed.

Synchronous timing equipment has made possible extremely accurate performance, with one stroke of the spot welder, of a sequence of operations consisting of weld, grain refine, quench and temper. Greater attention will be paid to "design for welding."

It is now realized that the effect on hardenability of a single element often is exceeded by the cumulative effect of the same total percentage of several elements, each present in small amounts. In specification of materials by engineers, the trend may


LURES TO LANDING CRAFT

be toward stipulation of mechanical requirements, with no mention of steel to be used, leaving steel selection to the metallurgist.

Hardenability is one metallurgical term that should be understandable, even to the most aloof engineer. It is not a foreign-language word, nor coined in honor of someone; it simply means the ability to harden (by heating and quenching).

Hardenability can be calculated from composition and grain size by methods devised by Grossmann, fairly accurate for steels of medium hardenability, but less so for those with very low or very high hardenability. It now appears unquestionable that hardenability specifications are coming in the not far distant future. At present, steel producers are not in a position to control hardenability consistently within the narrow ranges of some users; hence, outlets for "off heats" must be available.

As to addition agents, the most important and only generally-accepted effect of adding any of these agents to properly prepared steel is increase in hardenability.

—W. P. Eddy, Jr. *Machine Design*, Vol. 16, July 1944, pp. 127-132, 162, 164.

Welded Construction

Condensed from "Engineers' Digest"

In designing for fabricated construction, the effect of assembly and welding procedure on the product must be considered. Arrangement of machinery pads and bosses needs careful attention. Plug welding of pads in the center of plates whose width exceeds 12 times their thickness does not seem efficient, as it creates extra welding heat and requires more time. A single, thicker plate would be preferable.

To avoid any drumming effect, extensive, uninterrupted surfaces should have ribs, holes in the surface, gusset plates of a different steel, or the so-called "cell" construction.

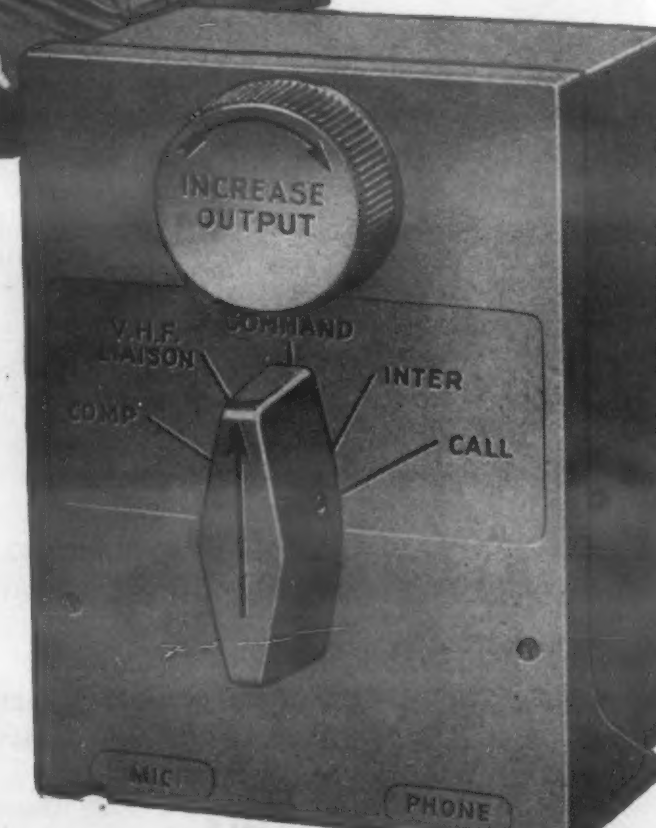
In many cases fabricated construction will not compare favorably with castings. Cast construction may be more economical, as labor costs in welding form one of the main factors in total cost. Bending single plates instead of welding two plates, and use of standard rolled sections, forgings and castings are often economical.

Machinery allowances can be smaller for fabricated construction than for castings. Allowance must be made for rolling mill distortion in heavy plates. Preparation of the welds may be accomplished by machining or flame cutting, preferably the former. Use of U-welds rather than V-type permits use of larger electrodes for first runs. Fillet welds are more economical with small throats and long runs.

The design work includes (1) development of the design itself, (2) a drawing to show the best way of cutting the material, and (3) a drawing to give instructions to the welding operators.

A lathe bed was built in three sub-assemblies, consisting of two outside wall portions and an internal stiffener. Separate heat treatment was applied to the sub-assemblies before final assembly, after which the

Official Photo U. S. Air Forces, Faces disguised.



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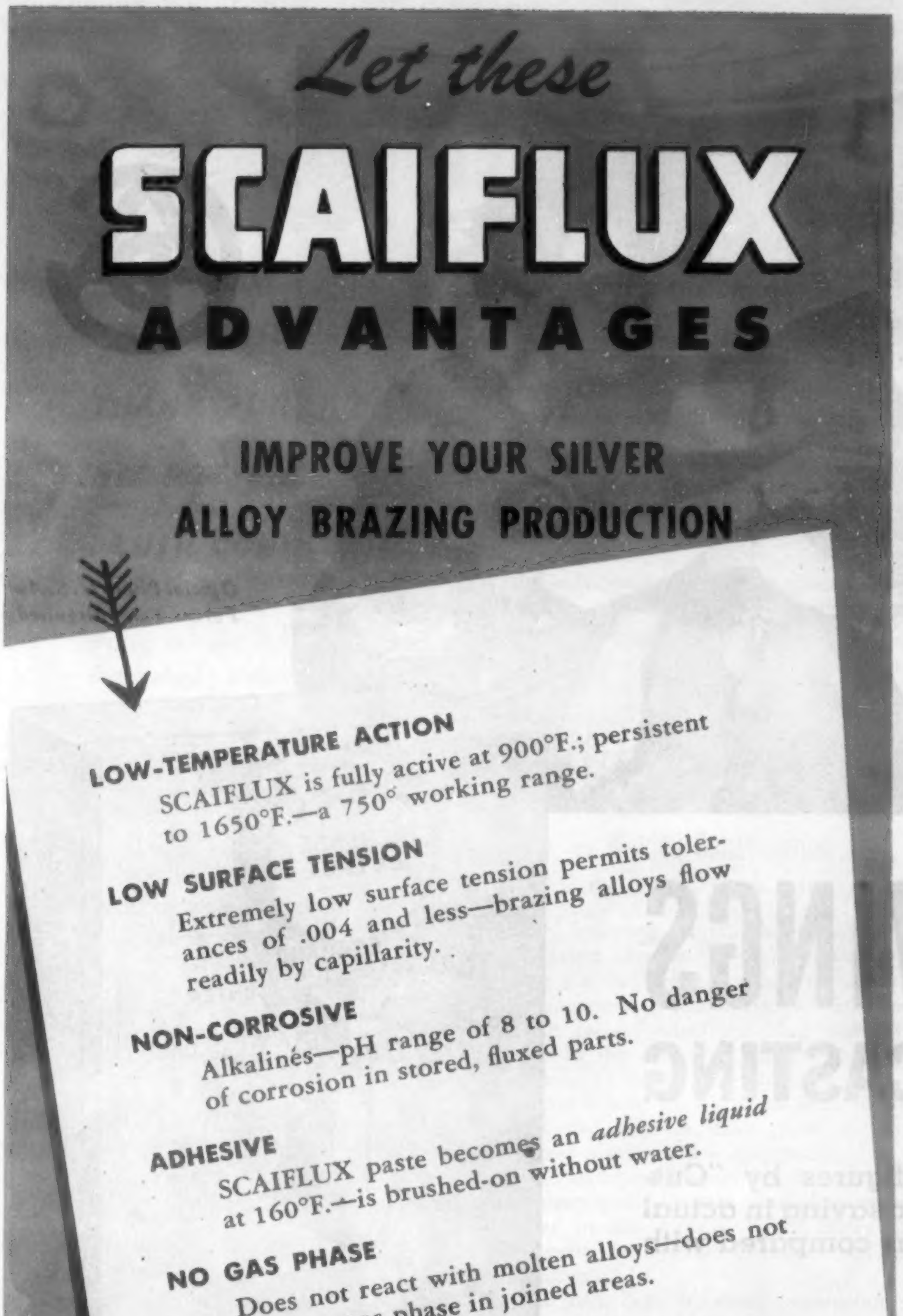

bed was heat treated as a whole. No measurable variation could be found in the bed after 12 months' service.

In a bedplate for a motor compressor, the main structure is bent from one plate and welded only at the corners. Instead of bosses for foundation bolts, as in castings, the tap plate is spotfaced and the stress exerted by the bolts is resisted by pipes welded between the top and bottom plates. Diagonal ribs strengthen against torsional stresses.

—F. Koenigsberger. *Paper, Inst. Mech. Engineers*, April 28, 1944; as abstracted in *Engineers' Digest*. Vol. 1, July 1944, pp. 466-468.

Magnesium Alloy in Design

Condensed from "Automotive and Aviation Industries"

For general design work, the following properties should be known: Tensile yield strength (0.002 in. per in. offset); ultimate tensile strength; compressive yield strength (0.002 in. per in. offset); ultimate compressive strength (when designing for the Army, assume this value is 1.5 times the compressive yield strength noted above); ultimate shear strength; bearing yield strength (0.005 in. per in. permanent set); ultimate bearing strength (when designing for the Army, assume this value is 1.5 times the bearing yield strength noted above); modulus of elasticity in tension and compression; modulus of elasticity in shear may be assumed to be equal to modulus of elasticity in tension—modulus of elasticity in compression divided by 4 (1—Poisson's ratio); Poisson's ratio (may be taken as 0.32).

Although the mechanical properties generally exceed the minimum specified, these specified values must be used in design except for the moduli of elasticity where averages may be used. If the manufacturer uses a quality control system coupled with stock segregation, it is permissible to use the minimum test values.

The accepted modulus of elasticity of 6,500,000 p.s.i. occurs only in the low stress range up to 1 to 2000 p.s.i., and is difficult to detect by test. At higher stresses up to the apparent proportional limit, the modulus is lower (5,700,000 to 6,500,000 p.s.i.). This variation in modulus should be considered for an accurate analysis of stability problems or statistically indeterminate structures.

It is suggested that the straight line column formula be used in the short column range until more data are available. In the long column range, Euler's equation for the buckling stress should be used. To aid in establishing design curves, it is often advantageous to utilize a nondimensional column formula.

These methods are valid only for columns having stable cross sections but not for local buckling or crippling failures and torsional instability failures for which very little test data are available.

—R. O. Brittan. *Automotive & Aviation Inds.*, Vol. 90, June 15, 1944, pp. 26-29.

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CONTENTS

Control and Instrumentation

Condensed from "Canadian Metals and Metallurgical Industries"

At the plant of Atlas Steels, Ltd., producing tool and special steels, furnaces for melting, heating, annealing and heat treating are carefully controlled. A pyrometrical laboratory services and checks all instruments.

In the gashouse, four 1½-lb. turbo blowers supply air for the gas producers. Air from the blowers is controlled by two diaphragms that operate in sequence. Approximately half of the gashouse output is washed gas. Gas analysis is taken on a 24-hr. sampler once a day.

In the soaking pits, the temperature controls are full proportioning with automatic drop correction. Pyrometers have a range of 1200-2600 F. The set-up for one pit consists of recording controller, electronic relay, valve drive unit and radiation-type temperature detector or rayotube.

Waste gases from 12 soaking pits are drawn into waste heat boiler by induced draft fan. The pressure impulse is taken from the main steam line, where pressure is 150 p.s.i. The boiler does not have a furnace pressure regulator. The soaking pit flue regulator acts in conjunction with the boiler.

The stoker fired boiler of 400 h.p., which operates at 150 p.s.i., is equipped with control of forced and induced draft. A furnace pressure regulator equipped with stabilizer operates louvres of induced draft fan.

Temperature control on the six-car type gas-fired annealing furnaces consists of three potentiometer-type controllers, electronic relays and 15 ft.-lb. drive units connected to a butterfly in the combustion airline to each zone. Chromel-alumel thermocouples in nickel-chromium protection tubes are placed in the side walls about 12 in. above the bottom of the load. The pyrometer range is 400-2400 F.

Control of Wire Annealing

Gas-fired, hood-type wire anneal furnaces consist of 6 movable hoods and 15 stationary bases. Each hood has an upper and lower control zone. Instruments consist of one 3-point dual control recording-controller on the lower zone, a single-point controller on the upper zone, two electronic relays, two 15 ft.-lb. drive units, and four thermocouples.

There are thirteen 3-zone and six 4-zone gun barrel furnaces. The 4-zone units have a capacity of 240 kw. and 3-zone 180 kw. Pyrometers are recording controller type, one for each zone.

The electric car furnace is a 3-zone, 2 chamber, with a capacity of 185 kw. Pyrometer-type controllers control either chamber.

Electric pit-type furnaces are of 650 kw. with 4 zones. Each furnace has its own pyrometers. Chromel-alumel thermocouples are placed in side walls. Rod hardening furnaces have 2 zones of 225 kw. and one of 4 zones and 450 kw. Pyrometer range is 200 to 2000 F. Thermocouples are chromel-alumel.

Oil-fired car furnace controls consist of

(Continued on page 1090)

Industry...

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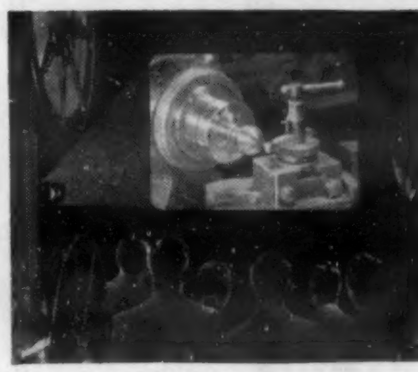

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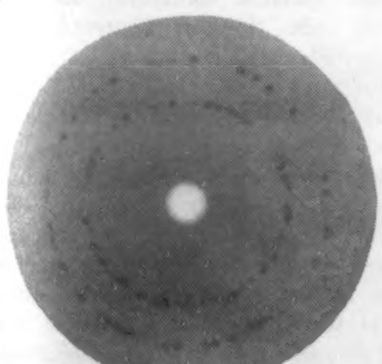
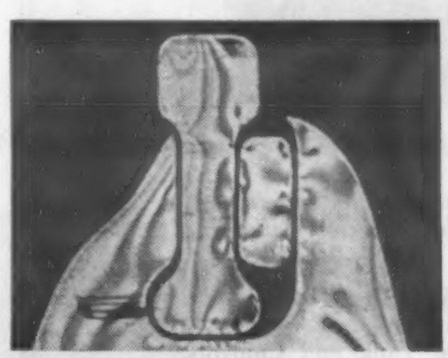


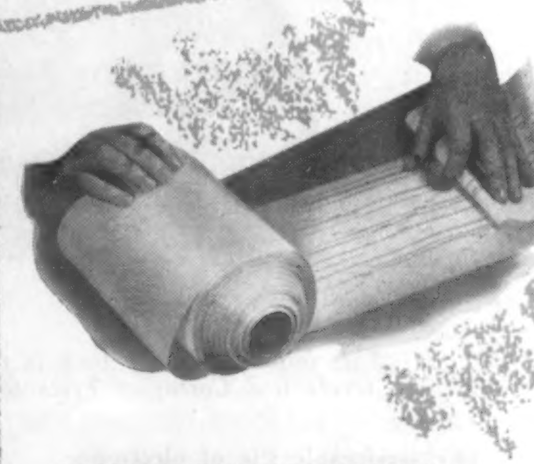
X-RAY DIFFRACTION—Reveals the invisible

Industry is finding many practical applications for crystal analysis by x-ray diffraction. Minute particles, too small to be seen by visible light, modify and diffract x-rays. Recorded on film, the x-rays form diffraction patterns which are of great value to metallurgists and engineers in the search for better materials and methods of metal-treating.



STRESS ANALYSIS—Previews performance

Photographic stress analysis studies, similar to the photo-elasticity illustration above, are playing an increasingly important part in product design. Study and analysis of an experimental model's behavior under simulated operating conditions enable predetermination of the product's performance.



INSTRUMENT RECORDING—Data reporter

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three potentiometer-type controllers, electronic relays, six 15 ft.-lb. drive units, six thermocouples and three transfer relays. Firing is done with twelve 1½-in. oil burners.

Oil-fired rolling mill furnaces have the same instruments as the soaking pits. Drive units have a capacity of 75 ft.-lb. Burners are connected to the drive by means of levers.

The oil-fired wire anneal furnace has 3 zones, controlled in six sections by three units. Each zone is fired with six 1-in. proportioning oil burners on each side of the furnace. The range of the pyrometers is 400-2400 F. Thermocouples are placed in the center of each zone.

In the continuous billet furnace each zone is separately controlled. Units are pyrometers, 1000 to 2500 F., calibrated for platinum-plus-10%-rhodium thermocouples, and electronic relays and valve drives of 15 ft.-lb.

—John F. Black. *Can. Metals & Met. Inds.*, Vol. 7, June 1944, pp. 38-41, 56-57.

Modern Views on Alloys

Condensed from "Journal of the Institute of Metals"

In order to limit the field, the elements of the third horizontal row of the Periodic Table are considered, with the addition of magnesium and aluminum of the second row, and tin and indium of the fourth row. This selection shows valency effects the transition process, and the development of ferro-magnetism.

All of these metals, with the exception of manganese, form one or more of the three typical metallic structures, *i.e.*, the face-centered cube, the body-centered cube, and the close-packed hexagonal.

To obtain some indication of how closely the atoms are held, and of their size, interatomic distances are plotted against atomic numbers. Interatomic distance shows a rapid fall from Group I to Group V, beyond which the contraction is not so marked, and after the atypical manganese there is a slight recovery. This general principle is seen in all the rows of the Periodic Table, with close cohesion about Group VI or VII. A plot of the melting points confirms this.

The explanation advanced for this phenomenon is that, in the first groups, there is an increasing number of electrons holding the structure together, and then a building up of the underlying ions.

In comparing atomic radii and ionic radii, it is apparent that the latter are smaller in the alkali metals, and the two are nearly equal for copper, silver and gold.

Ferromagnetism in iron is not a characteristic of crystal structure, but of distance between adjacent atoms. If they were farther apart, there would be influence upon each other.

Atomic Size Important

In forming alloys, the size of the atoms plays an important part. If the atomic diameters, defined as the smallest distance between two atoms in a crystal of the element, differ by more than 15% in two given metals, they do not fit together easily in solid solution.

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If one metal is relatively very electronegative compared to another, there is a tendency to form a stable intermediate phase instead of a solid solution. These principles permit the metallurgist to eliminate groups of metals in considering possible solid solution alloys. If he wants complete solid solution alloys, he picks out pairs of metals of equal valencies and equal sizes.

Maximum Solubility	Valency of Solute				
	1	2	3	4	5
Theoretical Cu or Ag	100	40	20	13.3	10
Actual	Ag-Au 100	Cu-Zn Ag-Cd 40	Cu-Ga Ag-In 20	Cu-Ge Ag-Sn 12	Cu-As Ag-Sb 7
Sol. in Cu	Ag, 5.4	Cd, 1.7	In, 10.9	Sn, 9.3	Sb, 5.9

Magnesium, a divalent element with hexagonal crystal structure, offers a system with lithium that suggests possibilities. Alloys are obtained with the eutectic temperature at just under 600 C. (1112 F.)

Aluminum, having face-centered cubic structure, and a trivalent element, is puzzling because of its low melting point. Alloyed with elements of lower valency, the result, if possessing the proper electron concentration, may be more stable as a mixture of two solid solutions.

—W. Hume-Rothery. *J. Inst. Metals* Vol. 70, June 1944, pp. 229-253

X-Ray Studies in Sheets and Wires

Condensed from "Journal of Scientific Instruments"

Stereographic projection forms the basis of the pole-figure method of representing prepared orientation of crystals in metals, states Dr. W. H. Taylor. Since a pole-figure represents only one plane, a series of pole-figures will generally be required.

When an initially unoriented specimen is rolled or drawn, preferred orientation usually becomes important only when the stress is well beyond that which would cause fracture in a tensile test. Both slip and twinning are involved, and these are controlled partly by the crystalline properties and partly by interaction at the grain boundaries.

In a rolled sheet of Elektron AM503 (magnesium with about 1.5% Mn), X-ray transmission photographs give the average orientation over the whole thickness, but by using surface-reflection photographs in a series and progressively etching away the surface, detailed information can be obtained of the orientation at any depth.

It was found that at the surface the crystals were oriented so that the hexagonal axis was parallel to the normal to the surface, but that a double orientation existed below the surface with the axes at $\pm 15°$ to the normal.

In examining wires and sheets of tungsten and molybdenum, H. P. Rooksby found that shows a texture characteris

tic of body-centered cubic materials, and that the scatter about this orientation decreases as the reduction in diameter increases, and in general is least in the center of the wire. Annealing at 1000 to 1100 C. (1830 to 2000 F.) does not change the texture.

Molybdenum sheet that has been rolled in two directions at right angles shows a strong tendency to develop cracks at 45° to the rolling direction. Glancing-angle X-ray photographs show that the effect of rolling at right angles to the original rolling direction is to perfect the parallelism of one of the crystal planes and the plane of the sheet. Other cube faces will then be perpendicular to the plane and at 45° to the rolling direction, giving cleavage planes along which breaks occur. Tungsten foil has shown similar cleavage-plane brittleness.

Orientation in sheet steels is a problem in electrical machine construction, said Dr. J. T. Randall. Silicon-iron containing to 4½% Si is widely used for transformers, the silicon increasing corrosion resistance and also electrical resistance, thus decreasing eddy current losses. Because of its brittleness it is difficult to produce. It is desirable to have the direction of easiest magnetization parallel to the lines of flux.

The presence of several glide planes complicates the mechanism of reorientation during rolling. Glancing-angle and transmission photographs are used in studying orientation by X-ray diffraction methods. The preferred orientation in iron-silicon after annealing is rarely the same as immediately after rolling. Sheet that has been twice cold-rolled, and annealed at 1100 C. (2000 F.) has a highly desirable texture. Little X-ray work has been done with the hot-rolled sheet.

—Proceedings of the Oxford Conference on X-Ray Analysis, March 31, 1944; as abstracted in *J. Scientific Instruments*, Vol. 21, July 1944, pp. 113-118.

New Fluoroscopic Methods

Condensed from "Industrial Radiography"

Fluoroscopy, like radiography, depends upon the shadow projection of material more or less translucent to X-rays. It produces no permanent record on a film, but only a shadow image on a fluorescent screen. This lack of record is compensated for to some degree by the fact that fluoroscopic examination permits viewing from a variety of angles, of importance where the alignment of assembled parts, as in non-transparent radio tubes, plastic molds with included metal parts, wiring, connections, etc.

The specimens should be enclosed in a cabinet with the X-ray tube, and may be placed in the cabinet manually, or on a conveyor, belt, or turntable. Tongs, directly or indirectly controlled from outside the cabinet, may be used to handle the specimens.

Screens are available today that are almost free from afterglow, *e.g.*, the zinc sulphide screen. They are also remarkably stable to X-rays, and have an emission spectrum coinciding with the maximum response region of the human eye. Doubling the voltage in the X-ray apparatus

increases the screen brightness about seven times.

This gain in brightness by use of higher voltages seems to promise an extension of fluoroscopic methods to heavier materials or to thicker sections in the future. For magnesium and aluminum the scattering effect does not decrease contrast appreciably, and for iron and copper the loss of contrast by increase of voltage does not reach prohibitive values.

It appears to be within the reach of fluoroscopy to inspect at 150 KVP thicknesses of aluminum to 2 in., of magnesium to 3 in., and of steel to about ⅜ in. The sensitivity is better than 5%. With voltage increased to 170 KVP, ½ in. of steel can be viewed with about 6% sensitivity, and at 200 KVP it may be expected that ¾ in. steel can be fluoroscoped with about 7% sensitivity.

Since shadows in motion are better detectable with the eye, an improvement of about 15% in intensity discrimination can be made if the specimen be moved during inspection.

The Photo-Roentgen process, developed for Army medical purposes, will prove to be of future importance in industrial inspection of mass production. It is a recording of the screen image on small film, later viewed at some amplification in an optical magnifying device.

A photoelectric cell method may be used in connection with the fluorescent screen to record deviations from a standard that cause slight variations in brightness on the screen. Applications are in checking the degree of concentricity of the conductor in a cable, or of variations in wall thickness of tubing.

—Mario Iona. *Ind. Radiography*, Vol. II, Spring, 1944, pp. 20-25, 28.

Metallography of Copper-Aluminum

Condensed from
"Zeitschrift für Metallkunde"

In order to find a satisfactory explanation for the eutectoid disintegration of the beta-phase and the nature of the intermediary phases, the diagram of state of the copper-aluminum alloys was investigated in the range from 8.5 to 15.6% Al in solid state dilatometrically and resistometrically.

There are indications in the alpha-solid solution range with higher aluminum contents for an ordered distribution of atoms with a weak degree of order. The limits of the heterogeneous range with eutectoid disintegration of the beta-phase adjoining the range of solid solution were found at 9.3 and 15.5% Al, the temperature of the eutectoid transformation at 575 C., and the concentration of the eutectoid with 11.9% Al.

Alloys with less than 12 to 12.3% Al behave quite differently in tempering and quenching than those with higher aluminum concentration. The former show a dependence of expansion on temperature. According to the quenching temperature, the structure can contain, alpha', alpha' plus beta', or beta' plus gamma' constituents, and these change the expansion coefficient.

—F. Bollenrath & W. Bungardt. *Z. Metallkunde*, Vol. 35, Aug. 1943, pp. 153-156.

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books

FOR METALLURGICAL ENGINEERS

Quantity Production and Design

HANDBOOK ON DESIGNING FOR QUANTITY PRODUCTION. *By Herbert Chase. Published by McGraw-Hill Book Co., New York, 1944. Cloth, 5½ x 8½ in., 517 pages. Price $5.00.*

This book should be of great value to the designing engineers who have to deal with and to choose between so many competing methods of fabrication and who want an unbiased, clear, and easily understandable story of the relative advantages and disadvantages, best methods of application, etc.

The book contains individual chapters on the design features, advantages and limitations of the more common metal forms — die castings, sand castings, screw-machine parts, stampings, forgings, cold-headed products and plastic moldings — and additional chapters making detailed comparisons between specific forms.

Particularly commendable are the "rules for design," which I believe cover every method of fabrication. Chapter 8 on "Plastic Moldings" is also outstandingly interesting and valuable.

Not all engineers will agree with certain of the facts and conclusions presented in the book. For example, the admonition to designers to let the foundryman specify casting alloy composition on the basis of properties desired will be unpopular, since the foundryman cannot possibly know or be advised of all the service factors that affect the choice of alloy.

There are some inconsistencies as to design limitations and tolerances in the different chapters on die castings. Also, the advantages of combination and unit dies are overdrawn, since for best tolerances and structure individual dies are preferable.

On page 90 and following, the table includes some alloys that are not commercially used and omits others. The notes on the usefulness of these various alloys do not always hit the ball; for instance, under heat treated aluminum-silicon sand casting alloy No. 2 with 6½ to 7½% Si is stated to be best suited for castings where maximum impact and corrosion resistance are desired. This alloy has less impact strength than other aluminum alloys listed in the same table.

An objectionable feature is the reference to many alloys by a proprietary trade name when other manufacturers are furnishing the same alloy without any restrictions. Alloys should be referred to by composition or by ASTM or SAE specifications unless they are patented.

On page 85, the statement is made that cast iron possesses good corrosion resistance; this is hardly correct. Also, on page 478, the cost of magnesium is given as 30c per lb. in the ingot, and again this is hardly in line with the facts.

It is regrettable that no mention has been made of powdered metals; also that under Plaster Paris Mold Castings nothing has been said about the so-called "Precision Casting" (Plaster Paris and lost wax) method; both of these are well worth the engineer's consideration.

Under "Design of Sand Castings," the table on composition and properties of non-ferrous sand casting alloys serves a useful purpose. An equally comprehensive table of non-ferrous wrought materials would be desirable, especially with regard to stampings and die-forged parts.

Many of these points would not be worthy of notice if it were not for the fact that the book might steer the design engineer along the wrong road in these respects, just because it is so good and authoritative in general.

—D. BASCH

Review of Engineering

20TH CENTURY ENGINEERING. *By C. H. S. Tupholme. Published by the Philosophical Library, New York,* 1944. *Cloth* 5½ x 9 *in.,* 201 *pages. Price* $3.00.

"20th Century Engineering" is, by its own statement, written primarily for the layman, but many engineers will probably find it of value as providing a brief, generalized, non-technical review of progress in branches of engineering other than their own.

While written from the British viewpoint, the subject matter includes much of recent American engineering developments. Construction details of several British, American, and German aircraft are shown.

The metallurgical section is concerned principally with the light metals. Some disagreement might be found with the author's grouping of material, as for instance the placing of ultra-violet light as a detecting instrument under electrical engineering, rather than physics.

The book suffers somewhat from censorship of details about subjects such as Radar, and does not profess to be encyclopedic over the entire broad field of engineering.

—KENNETH ROSE

Other New Books

THE PRACTICAL DESIGN OF WELDED STEEL STRUCTURES. *By H. Malcolm Priest. Published by American Welding Society, New York,* 1943. *Cloth* 5 x 8 *in.,* 153 *pages. Price* $1.00. Beginning with a brief discussion of welding processes and materials, this little book gives in concise form much of the information that the engineer in the field should have at his disposal. Qualifying procedures for welding applicants, codes of the American Welding Society, and such matters as stress distribution and temperature effects are given. The author was formerly a designing engineer for the American Bridge Co., and is now with the Railroad Research Bureau, so that beams and girders, columns and trusses come in for careful discussion.

ENGINEERS' DICTIONARY: SPANISH-ENGLISH, ENGLISH-SPANISH. *By L. A. Robb. Published by John Wiley & Sons, Inc., New York,* 1944. *Cloth* 5½ x 8 *in.,* 423 *pages. Price* $6.00. The material contained in this volume has been accumulated during more than 25 yr. The field of this volume is the vocabulary of civil engineering in all its branches, and many mechanical and electrical terms are necessarily included, as well as some of the terms of geology, chemistry and other sciences. No attempt is made to deal thoroughly with mechanical or electrical engineering, or with any subject except civil engineering and construction. The Spanish-English equivalents precede the English-Spanish.

HAUCK INDUSTRIAL COMBUSTION DATA. SECOND EDITION. *Published by Hauck Manufacturing Co., Brooklyn* 15, *N. Y.,* 1944. *Cloth,* 8¾ x 11¼ *in.,* 112 *pages. Free to those interested.* This is a reference book for any one concerned with the selection, installation, operation and maintenance of combustion equipment for either oil or gas on furnaces, ovens, kilns, retorts, and other heat processing equipments. The data are described as "down-to-earth" facts on industrial combustion and heating practice. The book is free to engineers, plant executives, etc., who request it on their company's stationery.

METALLURGICAL ENGINEERING news

Equipment • Finishes • Materials • Methods • Processes • Products
Alloys • Applications • Designs • People • Plants • Societies

Precision Surface Grinder

A new surface grinder, particularly adapted to precision grinding and fine finish in the tool room, is announced by *Continental Machines, Inc.,* 1301 Washington Ave., S., Minneapolis 4. It has a dependable accuracy that enables even green operators to do constant fine work.

With standard grit wheels, it produces a fine finish to within 6 micro in. New design permits closer inspection of work in process and greater convenience.

The base is recessed to provide knee room for the operator. Since the saddle extends only 8½ in. from the table, the operator sees the work without straining. Electrical controls are recessed into the front of the base for convenience.

Called the G-1 DoAll surface grinder, it has a table travel of 21 in., transverse travel of 7½ in., with vertical wheel head adjustment of 12 in., using a 7 by ½ by 1¼ in. wheel. The machine weight of 2200 lb. insures minimum vibration.

A hydraulic control unit eliminates all piping, and controls the five hydraulically actuated movements of the grinder. When under automatic operation, the cross feed screw disengages automatically.

An exclusive feature is the adjustable wheel guard that enables the operator to lower the guard to compensate for wheel wear or adjust for individual application. The guard is removable without taking off the wheel.

Apparatus to Determine Porosity

A patent for an apparatus that can determine the relative porosities of materials has just been issued to Stuart H. Hahn and Robert H. Judson and assigned to *The B. F. Goodrich Co.,* Akron, Ohio. The porosity is tested by the degree of vacuum in a chamber, which is an important part of the apparatus.

Chief object of the invention is to provide the mechanism for determining the relative porosities of various materials by drawing air or gases through the material and indicating the rate of flow. The apparatus was originally designed for testing the porosity of various types of sponge rubber, but it has many other applications, the company believes.

So small and compact that it can be easily lifted and transported with one hand, the apparatus consists of a vacuum chamber placed in contact with the material to be tested, a constant speed power driven fan for evacuating air from the vacuum chamber, an outlet port for emitting the air, and a pressure gage to measure the degree of partial vacuum in the chamber and indicating this on a fixed scale.

An arm connected with the manually-operated switch, which starts and stops the fan, forces and holds the measuring indicator in position when the switch is turned off.

The scale used with the apparatus is adhered to a piece of translucent plastic and is reproduced on a transparent piece of photographic film, with a lamp placed behind the printed scale so that the degree of porosity can be easily read.

With highly porous material, the vacuum created by operation of the apparatus will be slight, and this vacuum increases as the porosity decreases. The scale used with the apparatus may be graduated in absolute units or have no units, and be made to show the relative porosities of two or more pieces of material.

Because of its portability, the apparatus can be especially valuable as a demonstration device to show relative porosities of materials.

(More News on page 1114)

"BEATEN PATHS ARE FOR BEATEN MEN"

MIGHTY text for a postwar industrial sermon is that given by Eric Johnston . . . "Beaten Paths are for Beaten Men."

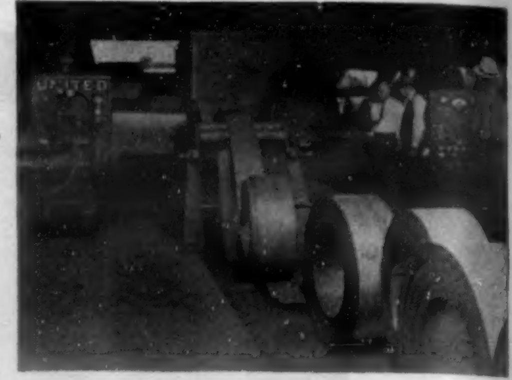
Anyone who has followed, even casually, his able leadership of the U. S. Chamber of Commerce will sense that his fight is for men who can change over from business procedures that simply ECHO, to those that SHOUT!

The trouble is that, to many, departure from the beaten path presents many unknowns which cause hesitation.

But, there is a painless and *known way* to blaze the trail . . .

Semi-Continuous Strip Pickler

A new design of semi-continuous strip pickler eliminates the welder or stitcher, looping pits and shear usually required, thus reducing space and installation and operating costs. It was made by the *United Engineering & Foundry Co.*, First National Bank Bldg., Pittsburgh, and placed in operation at the *Bopp Steel Corp.*, Detroit,



which produces cold rolled strip steel from purchased hot rolled bands up to 22 in. wide.

Tub pickling was previously used, but this was not fast enough for war times. The new installation is called "semi-continuous" because the front end of each coil is pushed through the first tank by the leveller unit from the coil box. At the opposite end of the first tank the strip is picked up by rubber covered pinch rolls, which feed the strip through the second tank, thence through several tanks to the drier and recoiler.

A visitor is impressed by the clean-cut and tidy appearance, accessibility of all parts, and absence of overhead fume ducts, the fumes being collected at the end of each tank by compact hoods. This pickler system has a definite application to small plants similar to Bopp.

Lengths of the pickle tanks are determined by the minimum thickness of the strip. The number of tanks is determined by tonnage required. The width of the line depends on the strip requirements of the individual plant.

The crew consists of a pickle house foreman, two men to operate the line, and a crane operator. Critical materials have been eliminated in construction. The tanks are so well insulated that heat losses are low. The cost per ton of pickled steel is very attractive.

In the accompanying photograph, the raw coils have been placed by crane on a gently sloping ramp. Here tie wires are cut, corners clipped and coils made ready to roll onto the coil box immediately after the tail end of the preceding coil has left the coil box.

● A die for coloring plastics is announced by *Krieger Color & Chemical Co.*, Hollywood, Calif. Called "Kriegr-O-Dip W," it does a complete job of washing, polishing and mordanting the plastic. The dye is heated in a vat at 160 to 170 F. Extruded, molded and fabricated parts can be dyed with this formula without crazing, etc. Dies are non-inflammable and can be reused.

Gold, as Parting Agent for Plastics

The *Eastman Kodak Co.,* Rochester, N. Y., is fulfilling a contract in record time through the development of a new parting agent and handling technique for the production of assembly fixtures of Durez phenolic casting resin.

This parting agent, gold, was plated to the master steel mold to solve two problems heretofore hindering mass production of plastic tools. Since phenolic plastic casting resins contain acid, it is necessary to protect metal forming molds from an unfavorable acid reaction.

Gold, resistant to all acids, aqua regia excepted, not only solved this, but with a thin coating of wax, proved to be an ideal parting agent in place of the usual organic material that had to be applied before each individual casting.

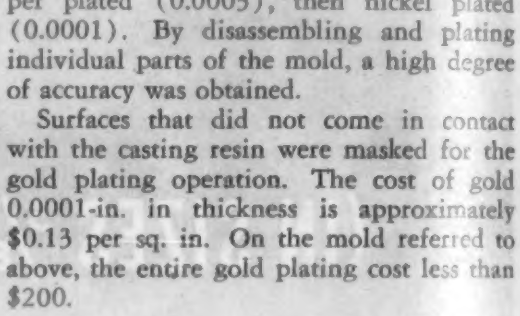
Through this application of gold plating and through their own handling technique, Eastman engineers are now casting plastic fixtures that will maintain a tolerance of ±0.001 in. in a total of 3 hr., ½ hr. of which is labor. A casting from this same mold, protected by an organic coating and utilizing traditional casting techniques, would ordinarily require 15 hr. to complete. Five hr. of preparatory labor would be consumed.

Preliminary to gold plating (Wittenberg Process—0.0001) the mold was first copper plated (0.0003), then nickel plated (0.0001). By disassembling and plating individual parts of the mold, a high degree of accuracy was obtained.

Surfaces that did not come in contact with the casting resin were masked for the gold plating operation. The cost of gold 0.0001-in. in thickness is approximately $0.13 per sq. in. On the mold referred to above, the entire gold plating cost less than $200.

Plier for Irregular Thicknesses

A new improved plier provides a self-setting pressure spindle to compensate for any variations found in the thicknesses of metal or parts clamped. This "Vari-grip," made by *Knu-Vise, Inc.,* Detroit, is particularly adapted to the aircraft industry,



where the holding of skin or metal on airplane wings during riveting operations presented a new problem.

It handles variations in thickness up to ⅜ in., is 8 in. long, and weighs 22 oz. Its throat capacity is 0 to ⅜ in.; depth, 2⅜ in.

Parts Cleaning System

A new parts cleaning system, combining the utility of two washers into one self-contained portable unit, is introduced by *Gray-Mills Co.*, Evanston, Ill. Large parts, requiring individual handling, are cleaned of grease and grime by a strong stream of solvent pumped from the tank below. Smaller parts may be washed in quantity in pouring them into a basket and immersing in solvent.

A 2-section shelf may be removed, giving access to the dipping tank below. The dipping basket rests on a hand-operated "swisher" device that agitates the fluid. Castings, gears, bearings, carburetors, air cleaners, machine products and tools may be washed quickly.

The unit is portable, equipped with a built-in gear-type pump, with a safety cover to eliminate fire hazards. The "Flo-Bac" solvent is used cold, and degreases without pitting or corroding. The same solvent is continually filtered. Two models are available.

● A new alkali cleaner, Nielco 1922, for brass, copper, bronze, German silver, gold, nickel, etc., has recently been introduced by *Nielco Laboratories*, 19720 Florence Road, Detroit 19. The manufacturer claims ability to clean all traces of oil from seams, pin holes, etc., at the same time removing all atmospheric oxides, thus eliminating additional operations.

Magnetic Separator for Ores

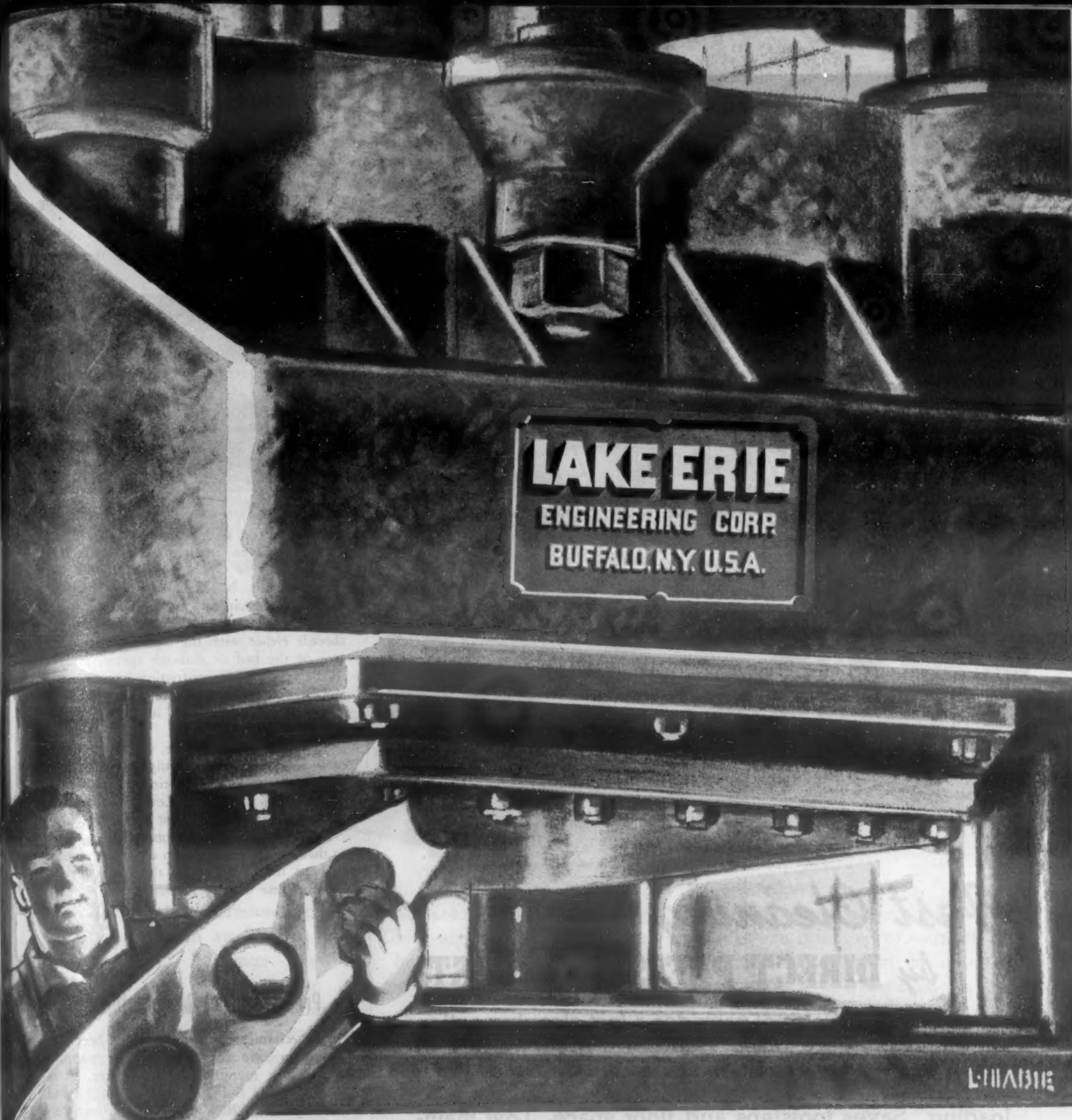
A new magnetic separator for concentrating of ores and minerals by the wet process is sponsored by *Stearns Magnetic Mfg. Co.*, Milwaukee.

The material goes into a simple enclosed spout and a controlled water pressure feed. This creates a high disseminating effect to spread the material in a thin, uniform layer to the underside of a submerged moving belt. Here it is picked up by the intercepting magnetic field and carried through the successive magnetic zones individually controlled by rheostats, which provide a clean product of concentrates, middlings and tails.

The water sprays are of ingenious design and conveniently located to control the direction and amount of flow to prevent contamination of material from floating impurities.

Clean separation by the Stearns Type "MWI" magnetic separator unit is further augmented by a special patented design of magnet pole pieces that subject the material to a zigzag movement as well as a rolling, cleansing action while in process.

The magnet poles and belt are submerged while the coil windings are not submerged, and, therefore, not subject to moisture or sweating. They are amply protected, however, against physical damage and water splash by metal jackets that provide ventilation by complete air circulation.


LAKE ERIE
ENGINEERING CORP.
BUFFALO, N.Y. U.S.A.

Turret Lathe for Carbon Electrodes

Claimed to be the first special machine built for manufacturing all sizes of carbon electrodes used in electric furnaces for making high grade alloy steels, a hollow spindle turret lathe has been turned out by *Mackintosh-Hemphill Co.*, Pittsburgh.

It performs all machining operations up to 31 in. in diam. and 12 ft. long, as well

as working on electrodes as small as 5 ft. long and 11 in. in diam. The machine is the property of *Great Lakes Carbon Corp.*, Niagara Falls, N. Y.

With mechanical equipment for both loading and unloading, the machine cuts threads either with the tapering bar at the rear of the bed or through special gearing in the apron. An anti-friction bearing headstock, with a 32-in. hollow spindle, is mounted on forced feed lubricated bronze bearings.

Each end of the spindle, with speed range of 6 to 120 r.p.m., is equipped with 3-jaw universal chucks, supporting the electrode while being machined. Levers for carriage operations are at the front of the machine.

An electric eye positions the headstock so that the loading rig can enter the spindle without interfering with the chucks, eliminating time usually needed to set up such jobs.

Press for Lock Manufacturers

A mechanical power press has been designed to care for requirements peculiar to the lock manufacturing industry. It is known as the S-40, and was designed and built by *E. W. Bliss Co.*, 53rd St. and Second Ave., Brooklyn 32.

A compact solid frame of rugged construction for standing loads beyond the rated capacity of the press was employed, with the die space and operating area concentrated for specialty dies. The new design involves a minimum floor space and overall height.

The press is equipped with a semi-automatic lubricating system to the essential bearings. Many standard parts of Bliss design, such as the clutch, brake collar, slide and pitman were incorporated in the No. S-40.

The operating speed is about 125 strokes per min.; however, considerably greater production can be obtained by attaching single- or double-roll feeds to the press. Operation of the feed can be front to back or back to front. The press is rated at 40 tons capacity at bottom stroke.

"Plastic Sandwiches," or Composite Plastics

"Plastic sandwiches" or composite plastic have been developed successfully by the structural plastics laboratory, *Glenn L. Martin Co.*, Baltimore 3, with its first application as a loop antenna mounting plate for the PBM "Mariner" airplane.

Two sheets of resin-impregnated woodpulp are sandwiched between built-up plies of resin-impregnated facing paper in a box-like jig. Alternate materials for face

plies include aluminum alloy, phenolic sheet, fibreglas and fabric.

The plastic sandwich can be given varying properties of strength, weight and density through the proper selection of material for the outer plies and resin and filler for the core. It can easily be molded to irregular shapes, and can provide special integral high density areas for special stresses, such as the attachment of fittings, without sacrifice of lightness or strength.

In the case of the loop antenna plate, a saving of 32% in weight, 60% in tooling costs and 50% reduction in overall cost has resulted. This plate provides a bearing surface for the antenna located aft atop the hull.

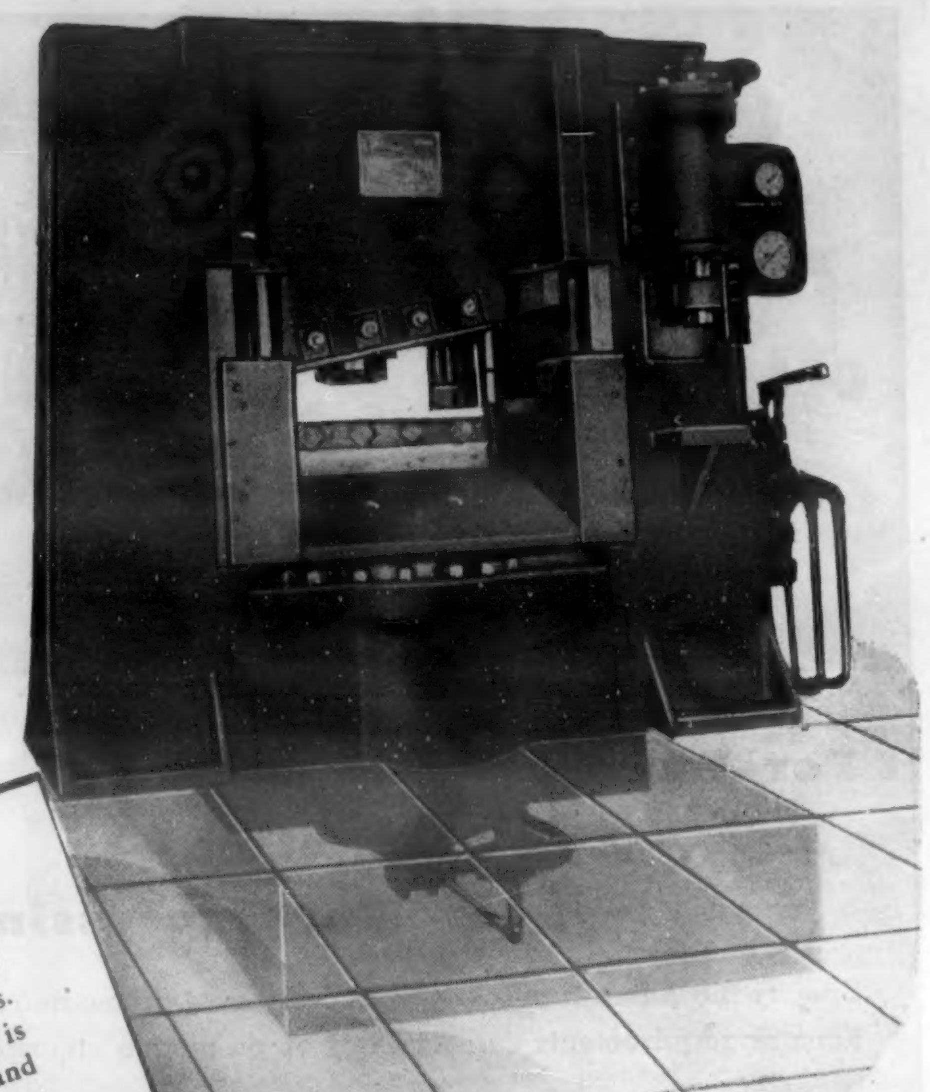
The top surface of this plate is flat, but the bottom is concave to conform to the hull's contour. Normally, this part would have been machined from phenolic fibre plate with the radius milled out by a convex cutter, 6 in. wide, and specially ground to the radius of 25 7/16 in. Three such tools would have been needed, to provide spares.

When the core and facing are assembled, they are placed in a Kirksite die providing the required radius and covered with a flat pressure plate. The die is then placed between electrically-heated platens in a hydraulic press. Heated to 300 F., the resin in the composite plastic flows as 5 to 10 p.s.i. pressure is applied. Each molded part is left in the press a short time to cure.

The rectangular sheets are placed in a router board and cut to the desired oval shape. After the edges have been sanded, attaching and locating holes are drilled in a jig. Later holes of various sizes are fly cut on the inner surface of the plates to allow passage of the antenna wiring.

THIS 600 TON PRESS

SHEARS COPPER BILLETS HYDRAULICALLY



Watson-Stillman hydraulic metal shearing machines have made it possible for war-geared industry to meet ever-increasing production schedules. In this highly-mechanized war, metal working is playing a major role behind the firing line, and Watson-Stillman hydraulic machinery—of many types and for many uses—has been right in the thick of the "production front."

Shown above is the latest Watson-Stillman 600-ton, self-contained Hydraulic Copper Billet Shear capable of shearing non-ferrous metal billets having a cross-section of 3 inches thick by 16 inches wide, and a shearing strength of 45,000 pounds per square inch. It operates at an advance and shearing speed of 63 inches per minute, and return speed of 250 inches per minute.

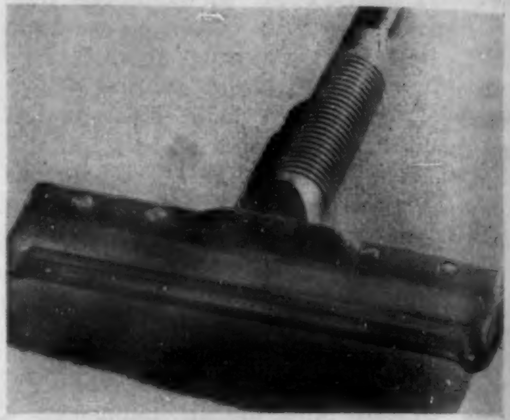
POST-WAR PROBLEMS are going to be easier to solve because of the technical advantages gained by the necessities of war-time production. Watson-Stillman engineers, backed by almost a hundred years experience in the manufacture of hydraulic machinery, offer you their services NOW, so that you can be prepared for the post-war problems of your industry. Now is the time to ask for Watson-Stillman advice. The Watson-Stillman Co., Roselle, N. J.

WATSON-STILLMAN

Hydraulic Equipment, Valves
Forged Steel Fittings

Flame Priming Nozzles

A flame priming and descaling nozzle that removes rust scales from steel plate and prepares it for painting is introduced by *Victor Equipment Co.*, 844 Folsom St., San Francisco. It is easily attachable onto any



standard Victor welding torch butt—or a butt can be furnished.

It has a spiral mixer and gas proportioner, which assures freedom from back-fire and flash-back. An "Airadiator" aluminum cooling section is at the nozzle head. Replaceable skid shoes are of Meehanite, with properly shaped lugs that allow it to be dragged at any suitable angle over metal surfaces.

The nozzle is in 4- and 6-in. ribbon flame widths. For inaccessible areas or rivet heads, special circular multi-flame nozzles are available.

Turret Attachment for Drill Press

A new attachment for drill presses that is claimed to increase the capacity of any drill press four times, has recently been announced by the *Chicago Drillet Corp.*, 919 N. Michigan Ave., Chicago 11. It is sold under the trade name Quadrill.

The unit is a precision-built rotary device that holds four tools, and the desired tool can be placed in work position by a "flick" of the finger, thus eliminating the necessity of changing tools, as in the single chuck drill press.

It will do all the work of any drill press, such as drilling, counter-boring, reaming, center-drilling, counter-sinking, spot facing and other operations. Yet, according to the manufacturer, because the Quadrill holds four tools, it actually permits one drill press to do the work of four.

Only the drill in working position rotates while the other three remain stationary for safety purposes. The entire unit is assembled to the quill of the drill press and is driven from the spindle.

Strict alignment and accuracy, as true as the drill press itself, are maintained. Hardened friction starter and driver assure clash-free synchronization of the driver teeth. The four hardened and ground spindles are fitted for No. 32 Jacobs chucks, or their equivalent. Ball bearings are in all spindle assemblies.

Small Barrel Plating Unit

A barrel plating unit suited for such small pieces as springs, catches, rings, pins, screws, etc., called the "Barel-Cel," is announced by *Precimet Laboratories*, 64 Fulton St., New York 7. It is a 2-gal. plating unit, originally designed for the plating of precious metal, but also satisfactory for copper, nickel, brass, silver, etc. plating.

It consists of adjustable cathode and anode, and a tilted tub that rotates slowly during the plating operation. The power unit electric motor can be plugged into any convenient outlet.

Current supply is furnished by two wire leads, fastened to the plating current bars. The tub is removable to permit flexibility in handling the solution, such as raising to proper temperature.

There is no waste of materials, such as in the basket method of plating. Its outstanding advantage is its size, which is unique in the field of barrel plating.

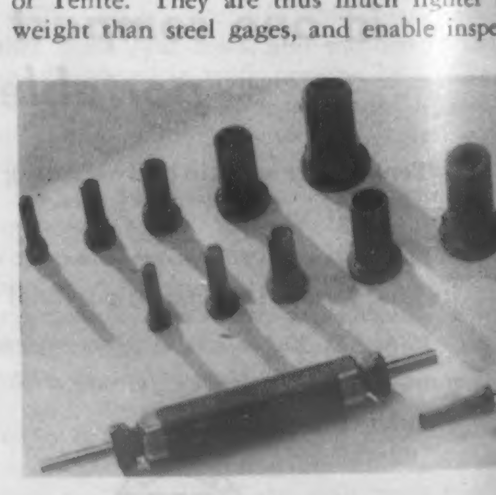
Colored Plastic Collets for Gages

Black and red collets of Tenite plastic, tapered and slotted to fit standard plug gage handles, increase the life of gaging surfaces. The use of Tenite for these collets prevents scratching or burring of the gaging surfaces; thus, most of the gage's length can be used.

As the "go" and "no go" ends are worn beyond allowed tolerances, they are simply cut off, and an unused end is ready for gaging. Red collets enable the quick identification of the "no go" members.

To facilitate resetting, the shoulder of the collet is notched for an end wrench, and a thin slot the length of the collet takes up slack in the locked position. Two shallow flat surfaces on the taper provide for dimensional adjustment under pressure.

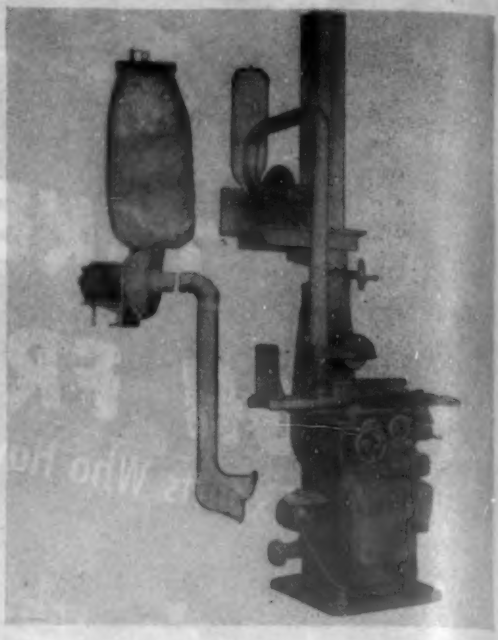
Handles of these gages are also made of Tenite. They are thus much lighter in weight than steel gages, and enable inspectors to make quicker, more accurate inspections.



Collets are turned from rod stock and marketed by *Turner Gauge Grinding Co.*, Ferndale, Mich. The plastic rod is extruded by *Detroit Macoid Corp.*, Detroit; handles are molded by *Federal Tool Corp.*, Chicago. Tenite is a product of *Tennessee Eastman Corp.*; Kingsport, Tenn.

Simplified Dust Collector

A dust collector for use with grinding and polishing wheels, etc., which runs from any electric light socket, is announced by *Leiman Bros.*, 107 Christie St., Newark 5, N. J.



This suction collector handles 600 cu. ft. of free air per min. with a 1/4 h.p. motor at 3500 r.p.m. It stands 47 in. high, with a 9-in. diam. dust bag, 3-in. pipe and elbows, and dust hood. It is a simplified individual dust collector for each machine.

Lathe Angle Plate

A new lathe angle plate with accessories, manufactured and sold by *Best Tools Corp.*, 482 Sunrise Highway, Rockville Centre, Long Island, N. Y., accomplishes many unusual operations on any standard make lathe, and eliminates the need for many costly special jigs and fixtures usually needed to machine intricate jobs on a lathe.

Known as No. 51, this lathe face plate attachment is positioned by a locating nose plus in the head stock spindle, and is then bolted to the face plate. It is equipped with an adjusting screw and the necessary pages so that by the use of size blocks or calipers work may be located with a high degree of accuracy.

Precision machined, No. 51 is readily set up on the lathe face plate, and without special jigs and fixtures it is possible to do any of a number of specialized machine shop jobs that are frequently required in making samples or in short or long production runs.

These include offset radius turning, cutting eccentrics, angle boring, turning compound angles, and other operations that are not ordinarily considered as straight lathe work. It is especially adapted to jig and fixture work where holes, straight or directional, must be held and spaced to close tolerances. This attachment converts the lathe into a miniature boring mill.

New Saw Blade

A new saw blade, designed to lessen or eliminate operator fatigue, is announced by the *DoAll Co.*, 254 N. Laurel Ave., Des Plaines, Ill. It is built for the rapid cutting of ferrous and non-ferrous alloys. Called the "Buttress" saw, the innovation in design of teeth permits rapid production, parallelism and close tolerance over the entire finished cut.

Tooth gullets are elongated to provide room for fast removal of chips to assure cool continuous cutting. Teeth are securely anchored to withstand shock, and made fast in their precision set position by heat treatment. High carbon steel of finest quality is used.

The saw is manufactured in widths from ¼ in. to 1 in., with various sets and pitches.

● A new jig to determine compression yield strength in aircraft design, developed by W. P. Montgomery and R. L. Templin, is being manufactured by the *Baldwin Locomotive Works, Southwark Div.*, Philadelphia. Common practice has been to obtain values for compression yield in sheet metal by testing sheets in packs. With this method it is possible to test a single thickness of sheet in compression, supporting the sheet in the jig with a multiplicity of small rollers. The extensometers are attached to the edges of the sheet. The testing of the material in single sheet form simplifies the technique. It offers possibilities in plastics as well as metals.

Smoke Remover for Foundries

Proper removal of smoke, fumes and hot air has been an important factor in boosting production of magnesium and aluminum castings 20 times over pre-war levels in the five non-ferrous metal foundries in New Jersey, operated by *Eclipse-Pioneer Div., Bendix Aviation Corp.*, Teterboro, N. J.

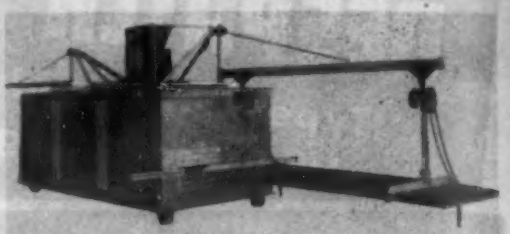
Twenty-four "iron lung" power ventilators, developed by the *Powermatic Ventilator Co.*, Cleveland, are used in the five foundries, each lung being capable of removing from 30,000 to 45,000 cu. ft. of air per. min. The lung was first tested over a brass melting furnace that formerly interfered with workers in other departments by spreading its fumes to all parts of the plant.

The lung discharges impure air so high above the roof that it will be impossible for it to re-enter via open doors, windows or idle ventilators. During a rain one can look straight up through the ventilator's unobstructed "throat" and see fumes being sucked upward, without getting wet. Downpours of rain are, in fact, shunted aside by the force of the discharged air stream.

Magnesium Preheat Furnaces

A new magnesium preheat furnace for sheets and plates, designed for 600 F. with capacity for seven sheets of magnesium alloy, up to 4 ft. wide, 12 ft. long and 1/4 in. thick, is sponsored by *James H. Knapp Co.*, 4920 Loma Vista Ave., Los Angeles 11.

For maximum usefulness, it is self-contained and mounted on four ball-bearing



double casters for movement to the presses where the magnesium is to be hot formed. It provides for loading and unloading through seven double doors on either end. On standard units, there are double doors on each end.

It is electrically heated, and equipped with three blowers on one shaft. Heating elements are in the plenum chamber in front of the blowers and extending the full furnace length. Using a Leeds & Northrup potentiometer recorded controller with special contacts, reduced heat input is provided for the "soaking" period, or for low temperature operation.

At the furnace ends, jib booms with chain hoists handle the hot tray loads. For moving convenience, they fold back over the furnace to make the overall dimensions approximately 9 ft. high, 9 ft. wide, and 17 ft. long. Booms extended, overall length is about 38 ft.

Timer for Resistance Welding Machines

A new precise electronic forge-pressure timer has been incorporated in its line of capacity discharge controls for use with stored-energy type resistance welding machines, it has been announced by the *Industrial Control Div., General Electric Co.*

The new timer, which is designed for dual pressure spot welding machines of the capacitor discharge type, functions to supply accurately timed forge-pressure, so that the required welding energy, cracks, indentations and sheet separation are reduced.

Calibrated in milliseconds, the timer consists of a timing circuit with a regulated d.c. source of voltage to assure accurate timing; the necessary electronic tubes; and a time-delay relay with fixed timing for compensating for the delay in the operation of the solenoid valve on the welding machine, so that the forge-pressure can be applied precisely at any point during the current discharge.

A feature of the new timer is that it is mounted on a small steel base so constructed that it can be added to any G-E capacity discharge control already installed, providing the resistance welding machine has a dual pressure system designed for this purpose.

Masking Jigs for Copper Plating

In a field where previously-used materials were severely limited, Plexiglas masking jigs are now used exclusively in the copper plating of carbon rings by the *Morganite Co.*, Long Island City, New York, manufacturers of carbon specialties.

Because of its machinability, dimensional stability, and light weight, Plexiglas has

been found most successful, not only reducing rejects but also stepping up production rates. Carbon rings to be plated are inserted in grooves 1/64-in. wide on either side of the Plexiglas jig rings.

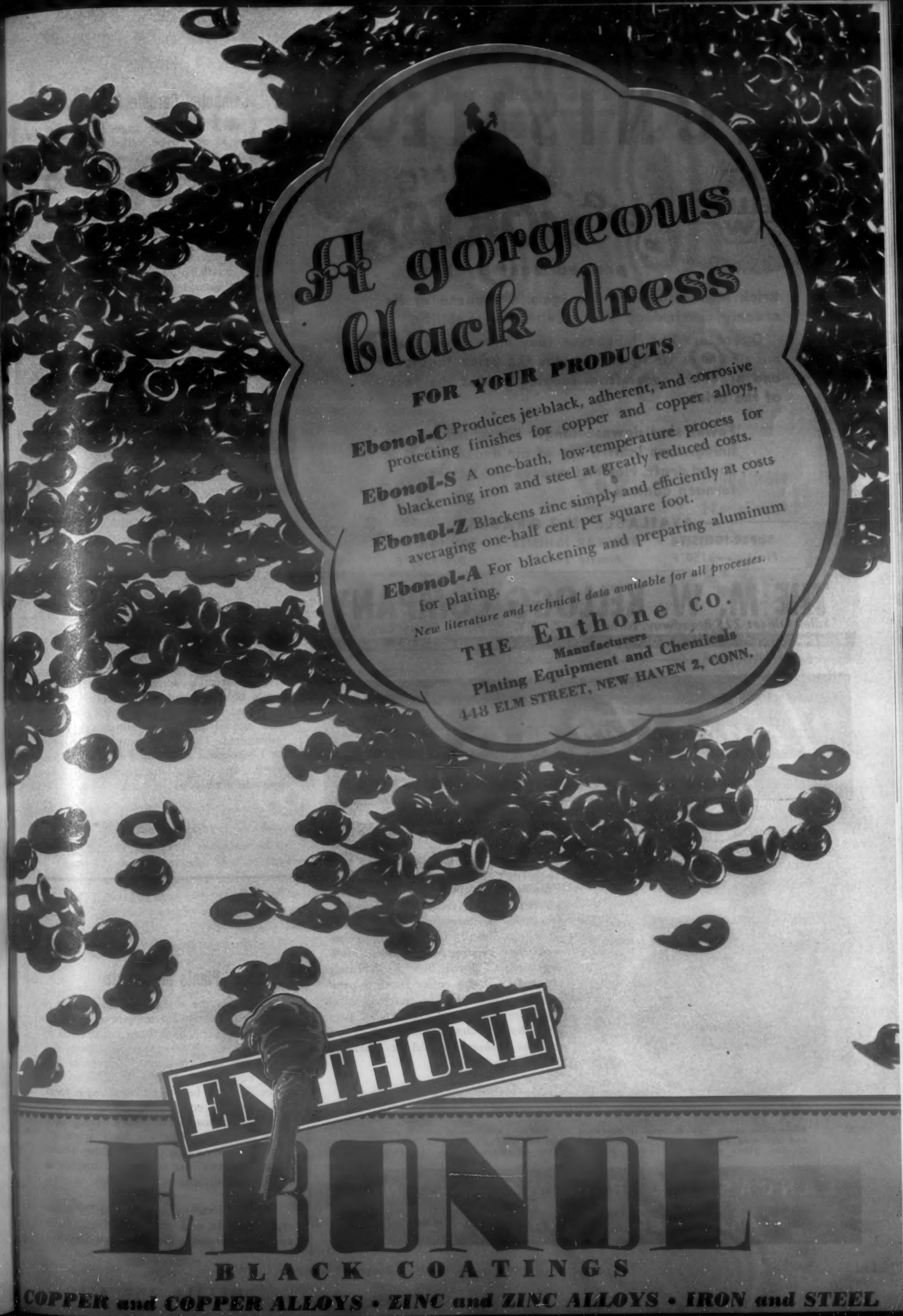
They are then mounted in gang fashions on a carbon rod; electrodes are attached, and the entire assembly is suspended in a plating solution. The durability of these Plexiglas jigs and their resistance to the plating solution makes them highly practical.

In the top photo, a series of Plexiglas masking jigs is mounted gang fashion on a carbon rod. In the lower photo, carbon rings, plated except for the narrow rim protected by the Plexiglas masking jig, are shown as they are removed from the rod.

Film for Recording Surfaces

What the sponsor calls a revolutionary method of surface inspection is the "Faxfilm." It is a plastic film, one surface of which is softened by a solvent, then pressed into contact with the surface to be examined. This leaves a 3-dimensional imprint on the film, which is later placed in an ordinary projector and flashed upon the screen—perhaps at 100 magnifications. The film kits are put out by *Rex D. McDill*, engineer and physicist, 5109 Mayfield Road, Cleveland 21.

It takes less than a minute to make the exposure, it requires no complicated instruments to apply, is inexpensive, and makes an accurate replica. A complete kit consists of roll of film, bottle of solvent, moistener and mounting frames for adapting it to a projector machine. It can be used on several materials, such as metal, wood, paper, etc.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Cemented Carbide Gage Blocks

Cemented carbide gage blocks in the Hoke (square) type, called "Carblox," are announced by *Lincoln Park Industries, Inc.*, Lincoln Park 25, Mich. They are designed as a series of wear blocks to be used on the ends of a gage block build-up, since they greatly reduce the wear error in gage block use and supplement and increase immeasurably the useful accurate life of present gage block sets. They act as protective anvils, preventing wear on the less wear-resistant steel blocks.

Carblox are practically non-magnetic, and are highly resistant to corrosion. Their square form allows them to be handled easily. They provide large symmetrical working surfaces and greatly reduce wear by overcoming the tendency to wring the gage blocks together, always in the one direction.

Hoke-type Carblox are 0.950 in. sq. with 0.260-in. holes, and are available in either "A" accuracy (0.000004 in.) or "B" accuracy (0.000008 in.) in sets of two 0.050 in. or 0.100 in., in sets of four (two each of 0.050 in. and 0.100 in.), and in sets of fourteen varied sizes.

This set of fourteen, supplemented with the standard 81-piece set of gage blocks, provides build-ups of practically any desired range. Special size Hoke-type Carblox can be furnished.

● Formerly the aileron quadrant on the B-26 Marauder, used in connection with a cable drive to activate the ailerons, was made of aluminum alloy, weighing 7.985 lb. Now a plastic part, weighing 7.11 lb., and outwearing the aluminum, has been substituted. The part is compression molded by *Continental Diamond Fibre Co.*, Norristown, Pa., from mascerated fabric-base phenolic (celeron).

Plants and Slants

To aid in the design and equipment of plants, particularly for the post-war, "industrial dollhouses" have been constructed by *Westinghouse*. Carved wooden figures represent workers, machines, conveyors and other equipment. Hence, a projected new plant can first be built in dollhouse form, and men and equipment moved about, as if on a chessboard, everything having been built to scale. Floor and aisle space are ascertained accurately. These "three-dimensional previews" are considered superior to former two-dimensional drawings.

An American boy, former foundry worker, drives his tank through Africa, Sicily and Italy. At last a German 88 writes finis

to him. But his soul goes marching on and back to the old foundry. As a phantom he talks to his old foundry buddies who are planning to leave the foundry for "soft" jobs. That is the gist of an impressive motion picture, "Men of Fire," put out by the *Motion Picture Branch, War Dept.*, Industrial Services Div., Room 1315, 1501 Broadway, New York 18. It is well worth showing before plant employees.

More than 20,000 war workers in the Chicago district plants of the *Carnegie-Illinois Steel Corp.* have been paid $1,750,000 in lieu of vacations to enable continued maximum production. The major part of such employees are in the Gary steel works and sheet and tin mill.

The *Wyckoff Steel Co.* has bought the properties of the *Empire Finished Steel Corp.* at Newark, N. J., and Putnam, Conn.

Alloy Rods Co., York, Pa., one of the world's largest manufacturers of stainless steel electrodes, is building a 2-story brick structure of streamline design. Complete laboratory facilities for chemical and metallurgical control and research are to be included.

H. K. Porter Co., Inc., Pittsburgh, has bought the *Fort Pitt Steel Casting Co.*, McKeesport, Pa., maker of pressure and alloy steel castings, with capacity of 1500 tons per month. Porter now operates six plants.

In some industrial departments as many as 85% of the jobs can be performed by disabled veterans with limited handicaps, it was learned by *Westinghouse* after a survey of 25 of their plants and 35 manufacturing and repair units. Jobs done with one eye are 85%; by the deaf, 82%; with one leg, 19%; with men using crutches, 17%.

The *United States Steel Products Co.*, *U. S. S. Steel* subsidiary, has acquired the manufacturing assets of the *Bennett Mfg. Co.*, Chicago and New Orleans, maker of steel drums. The purchaser is a sheet steel fabricator.

Four well-known industrial designers and architects have joined forces in a new firm, with headquarters at 228 E. 61st St., New York 21. They are Ruth Gerth, George Kosmak, Alexander Kostellow and Rowena Reed.

Though awarding of Army-Navy "E"s may seem a common occurrence, less than 4% of our total war manufacturing plants have received them. *Handy & Harman* recently won their fifth "E." The *Edward G. Budd Mfg. Co.*, Philadelphia, also received the fifth "E" recently, and was told they may retain the flag for a whole year, instead of the usual six months, before being considered for renewal.

A new record in continuous group operation of blast furnaces has been established at the Indiana Harbor plant, *Inland Steel Co.*, where five furnaces have maintained uninterrupted production for more than four years. Last year it was considered noteworthy when the five furnaces had com-

pleted three years of uninterrupted group production. With another year of service added without a shutdown, the record is considered remarkable.

Frostrode Products has moved to a larger plant at 19929 Exeter, Detroit 3, the new facilities to permit stepped-up deliveries of refrigerated welding units, resistance welding electrodes, etc.

Dresser Mfg. Co., Bradford, Pa., will call a meeting of stockholders on Oct. 16, preparatory to acquiring the assets of *International-Stacey Corp.*, Columbus, Ohio.

The *Graham-Paige Motors Corp.*, Detroit, has acquired the *Warren City Mfg. Co.*, Warren, Ohio, which constructed a $9,000,000 plant in 1942. Joseph W. Frazer, leading automobile executive, was recently elected chairman of the board of Graham-Paige.

Rheem Mfg. Co. will operate a plant at Williamsport, Pa., to produce 8-in. projectiles. The company has already turned out more than 3,000,000 shells.

The electrode service engineering department of *National Carbon Co., Inc.* has been reorganized and enlarged. An increased number of technical advisers have been assigned to act as field consultants on carbon and graphite electrodes in electrometallurgical and electrochemical applications.

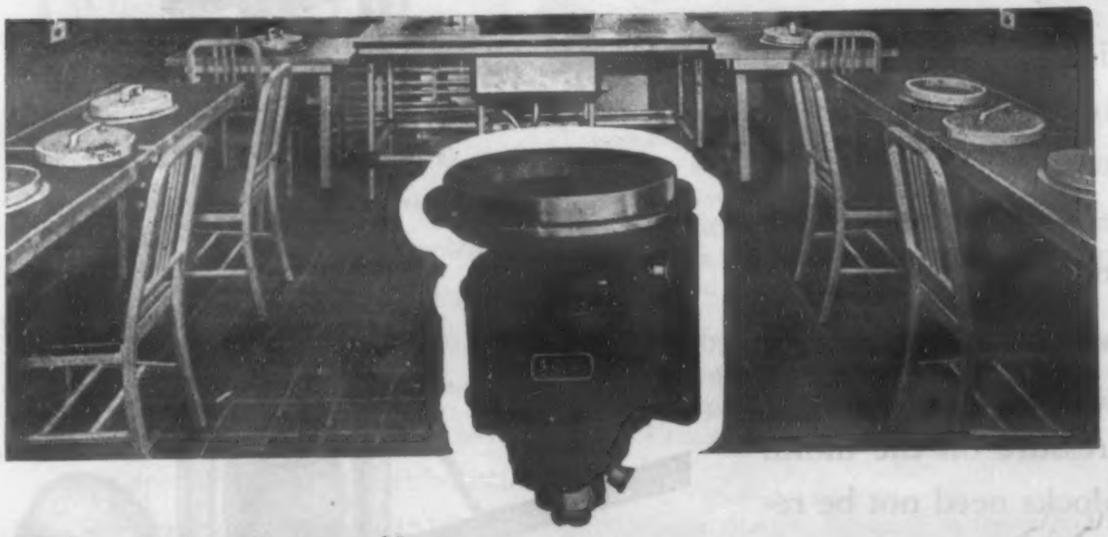
News of Engineers

A. J. Hanlon has been appointed production manager of Harvill Corp., Los Angeles, maker of die castings for airplanes, having recently retired as manager of the production department, International Nickel Co. He has had over 25 years experience in the production of metals and their products.

Ernest H. Wyche, formerly in the metallurgical department of Carnegie-Illinois Steel Corp., is now research engineer with the Titanium Alloy Mfg. Co., Niagara Falls, N. Y.

Wayne Martin, formerly assistant materials engineer, Sperry Gyroscope Co., Inc., has been made sales engineer, National Smelting Co., Cleveland. He has been chairman of the program committee, Aluminum and Magnesium Div., American Foundrymen's Assn., and has served as metallurgist with Beryllium Corp. of Pa. and General Bronze Corp. He will specialize in the application of aluminum and magnesium casting alloys.

E. E. Le Van has been elected president of Haynes Stellite Co., unit of Union Carbide & Carbon Corp., succeeding the late Francis P. Gormely. For many years he has taken a leading part in making available to industry Haynes Stellite chromium-cobalt-tungsten alloys and other special alloys. He is the author of several articles on metallur-



gical and mechanical engineering subjects.

M. M. Clark has joined Climax Molybdenum Co. as metallurgical engineer for the Ohio district, making headquarters at Canton. Previous connections have been with United Alloy, Central Alloy and Carnegie-Illinois Steel Corporations.

R. A. Hartman, for the past four years master mechanic for the Crosley Corp. in charge of tool design, process engineering, tool room and layout of production lines, has joined Kropp Forge Co. and Kropp Forge Aviation Co., Chicago, as superintendent of the machine shop. From 1923 to 1936, Mr. Hartman was superintendent of the Cincinnati Precision Instrument Co., Cincinnati. Between 1936 and 1940, he conducted his own designing and engineering service.

R. G. Wingerter, for six years industrial engineer, Timken Roller Bearing Co., has become assistant chief engineer, Industrial Div. He belongs to several technical and civic societies.

Dr. William A. LaLande, Jr., formerly director of research, Attapulgus Clay Co., has joined the research and development department, Pennsylvania Salt Mfg. Co., as director of research.

Robert L. Irvin has been appointed works manager, Graham plant, Pittsburgh Screw & Bolt Corp. He succeeds *George H. Lee, Sr.*, who will do experimental and advisory work for all plants of the corporation.

Ralph W. Hisey has been promoted to vice president in charge of manufacturing and engineering of both the brush and machine divisions of the Osborn Mfg. Co., Cleveland. He has been with the company for over 30 years. *Hugh M. Little* has become works manager of both divisions. He was once with the Ohio Crankshaft Co. and the American Bantam Car Co.

H. W. Christoffers, L. T. Dupree and *R. B. Schneider* have recently joined the staff of Arthur D. Little, Inc., Cambridge, Mass., industrial research organization. Mr. Christoffers was previously with Commercial Filters Corp., Mr. Dupree with Servel, Inc., and Mr. Schneider with the central development group of Allied Chemical & Dye Corp.

M. J. Bobo, author of several papers on industrial combustion control, has been made assistant general manager of sales for the Hagan Corp., Pittsburgh. He is a member of the Association of Iron & Steel Engineers and other societies.

Charles L. Saunders has resigned as branch chief of the Office of Civilian Requirements to become vice president of Wheelco Instruments Co., Chicago. He has made contributions to the science of instrumentation in many industries, including metals, and is versed in measurement and control of temperature, pressure, flow, combustion and speed.

Don J. Peeps, of the engineering staff, has been appointed chief engineer, De Vilbiss Co., Toledo, Ohio.

Briefs on Associations, Promotions and Education

Advance reservations of display space in the War Conference Displays and National Metal Congress, Cleveland, the week of Oct. 16 have broken a 26-year record. Nearly 1000 metal experts are collaborating in the preparation and presentation of some 150 lectures.

The Meehanite Research Inst. of America, Inc., Pershing Square Bldg., New Rochelle, N. Y., has available for use by interested societies a motion picture entitled "The Flow of Metal into Molds." The film, in color, shows the action of molten metal as it is poured into molds of various sizes, shapes and complexities. Prints will be loaned upon request. The film consists of two reels and is for 16-mm. projection without sound.

Perry D. Helser, formerly chief, Magnesium Branch, WPB, has been elected secretary-director of the newly-formed Magnesium Assn., 30 Rockefeller Plaza, New York. The membership consists of producers, fabricators, smelters and consumers of magnesium, numbering 33. Its purpose is to develop and increase the use of magnesium and its products, and to correlate technological progress. E. S. Christianson, vice president, Apex Smelting Co., Chicago, is president; C. G. Loomis, president, New England Lime Co., Canaan, Conn., is vice president; and C. E. Larson, manager of operations, White Metal Rolling & Stamping Corp., Brooklyn, is treasurer.

A prize essay contest was recently conducted at Tuskegee Institute, Alabama, under the direction of Prof. W. C. Curtis, School of Mechanical Industries. W. S. Rockwell Co., New York, manufacturer of industrial furnaces, offered $100 as a prize for a paper on heat treating of metals. It was won by Alphonso R. Ogletree on the topic, "The Process of Heat Treating Steel for Practical Uses."

Dr. Edward V. Condon, associate director, research laboratories, Westinghouse, has been elected member of the National Academy of Sciences, based on outstanding contribution to the field of science. Dr. Condon has interpreted spontaneous emission of alpha particles from materials like radium.

The American section, Society of Chemical Industry, has elected Dr. Norman A. Shepard, American Cyanamid Co., as their chairman, and Frank J. Curtis, Monsanto Chemical Co., as vice chairman, to serve until July 1945.

Balloting ceased Oct. 3 on officers of the Army Ordnance Assn., Washington. Nominated for president was Benedict Crowell, Cleveland, by profession a mining engineer.

The Franklin Institute, Philadelphia, has received the Ordnance Distinguished Service award in recognition of scientific and engineering achievement and "in developing weapons of increased precision and longer service life and for long term technical advisory service in peace time." Battelle Memorial Institute, Columbus, also received this award, and also for "scientific and engineering achievement."

"An almost overwhelming demand for

space" is being encountered by managers of the third National Chemical Exposition and Industrial Chemical Conference at the Coliseum, Chicago, Nov. 15 to 19. Metals will receive thorough treatment in the technical papers.

At the sixth annual meeting of the American Coordinating Committee on Corrosion, 4400 Fifth Ave., Pittsburgh, Frank L. La Que, Development & Research Div., International Nickel Co., was elected chairman.

Dr. William Blum, chief, Section of Electrochemistry, U. S. Bureau of Standards, has been awarded the eighth Edward Goodrich Acheson medal and $1000 prize of the Electrochemical Society. Dr. Blum has been instrumental in standardization of electroplating methods and of plating formulas.

A large exhibit that will include hundreds of plastics items used in ordnance will be a feature of the fall convention of the Society of the Plastics Industry at the Waldorf Astoria, New York, Nov. 13 and 14.

Additional training courses for plant personnel in control and improvement of the quality of manufactured products through the application of statistical principles are announced by WPB. Eight-day full time courses are being given at the universities of Tennessee, Oklahoma, Nebraska, and Iowa; at Princeton and A & M College of Texas.

The American Rocket Society has elected officers for the coming year, and hopes to resume frequent meetings, eliminated because of war duties of officers and members. The new president is James H. Wyld, research engineer, Reaction Motors, Inc., Pompton Lakes, N. J.

House Organ Notes

Aluminum Progress, Reynolds Metals Co., Vol. 1, No. 2.

Here is another new publication in the metals field. The following are perhaps heretofore unpublished facts about aluminum foil. Reynolds can roll 60,000 sq. in. of foil from 1 lb. of aluminum. Reynolds has perfected a laminated foil which, as packaging material, affords almost as much protection as solid metal, though costing and weighing much less. A foil-covered cannister, such as used to house dental impression plaster, proved moisture-proof after a salt spray treatment of 400 hr., though the drawn black iron ends showed considerable corrosion.

Paint Progress, New Jersey Zinc Co., Vol. 5, No. 2.

Phosphorescent coating on tape to provide ships' interiors with an emergency light source that permits movement of personnel during blackouts is a novel application of luminescent pigments. The tape is prepared by coating a fabric, 4 in. wide and several yards long, with a phosphorescent pigment, and with a suitable adhesive on the reverse side. It is applied to walls of passageways, exits, mess halls, etc., and to mark and identify obstructions. It absorbs radiant energy from the ship's regular

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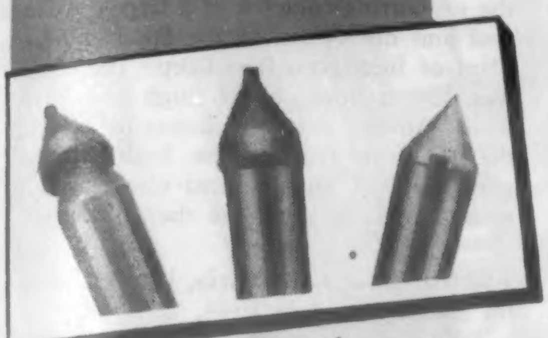
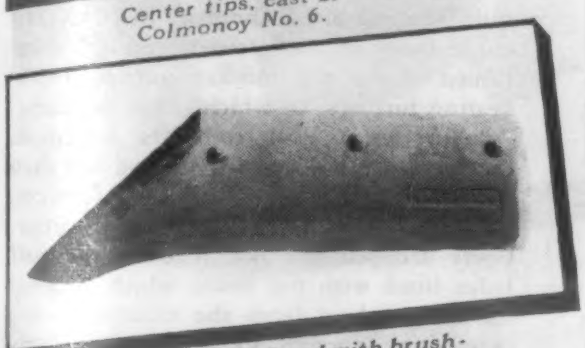
On the home front—COLMONOY, applied to plow shares and farm implements, is helping keep food production up.

COLMONOY Hard Facing Alloys are valuable in every industry facing the problems of wear and corrosion. They are available in many different grades, with wide ranges in Rockwell hardness, and have effected tremendous economies when applied to oil well drilling and refining equipment, machine tools, agricultural implements, cement mill machinery, valves, chemical processing equipment, engine parts, and countless other parts subject to severe wear.

COLMONOY alloys are available in the form of paste, welding rods and castings.



Center tips, cast of Colmonoy No. 6.



Plow share, hard-faced with brush-coated Colmonoy Sweat-on Paste.

Pump shaft sleeves and wear rings of Colmonoy No. 6.

High pressure valve stems and seats, hard-faced with Colmonoy No. 4.

Catalogs on Request

Describe all grades of COLMONOY Ferrous and Nickel base alloys, illustrate a wide variety of applications and include charts showing Rockwell C hardness, specific gravity, melting points and composition of all grades. Write today.

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lighting system, later emiting it as visible light when the regular lighting system is turned off.

Vernon Alcoan, Vernon Works, Aluminum Co. of America, Aug. 21, 1944.

Potential post-war volumes of accumulated demand for common household items have been computed by S. H. Slichter, professor of economics at Harvard. Expressed in millions of units they are: Vacuum cleaners, 3.5; clocks, 7.2; radios, 23.0; refrigerators, 5.2; electric irons, 10.3; washing machines, 3.1; waffle irons, 1.5; percolators, 3.7; toasters, 4.5.

Welding Briefs, Metal & Thermit Corp., May-June, 1944.

"Requiring less time than a second hand takes to travel around a watch dial, 1200 tons of steel were brought to the ground as molten Thermit steel and slag bit through the supporting columns of a large traveling coal and ore bridge at the South Chicago plant of Interlaken Iron Corp. The bridge was 300 ft. long, 80 ft. high and 30 ft. wide. Around 4 of 8 columns holding up the structure retorts were built, charged with Thermit, then ignited electrically. It took 51 sec. to complete the razing job."

The Otis Sheet, Otis Works, Jones & Laughlin Steel Corp., July 1944.

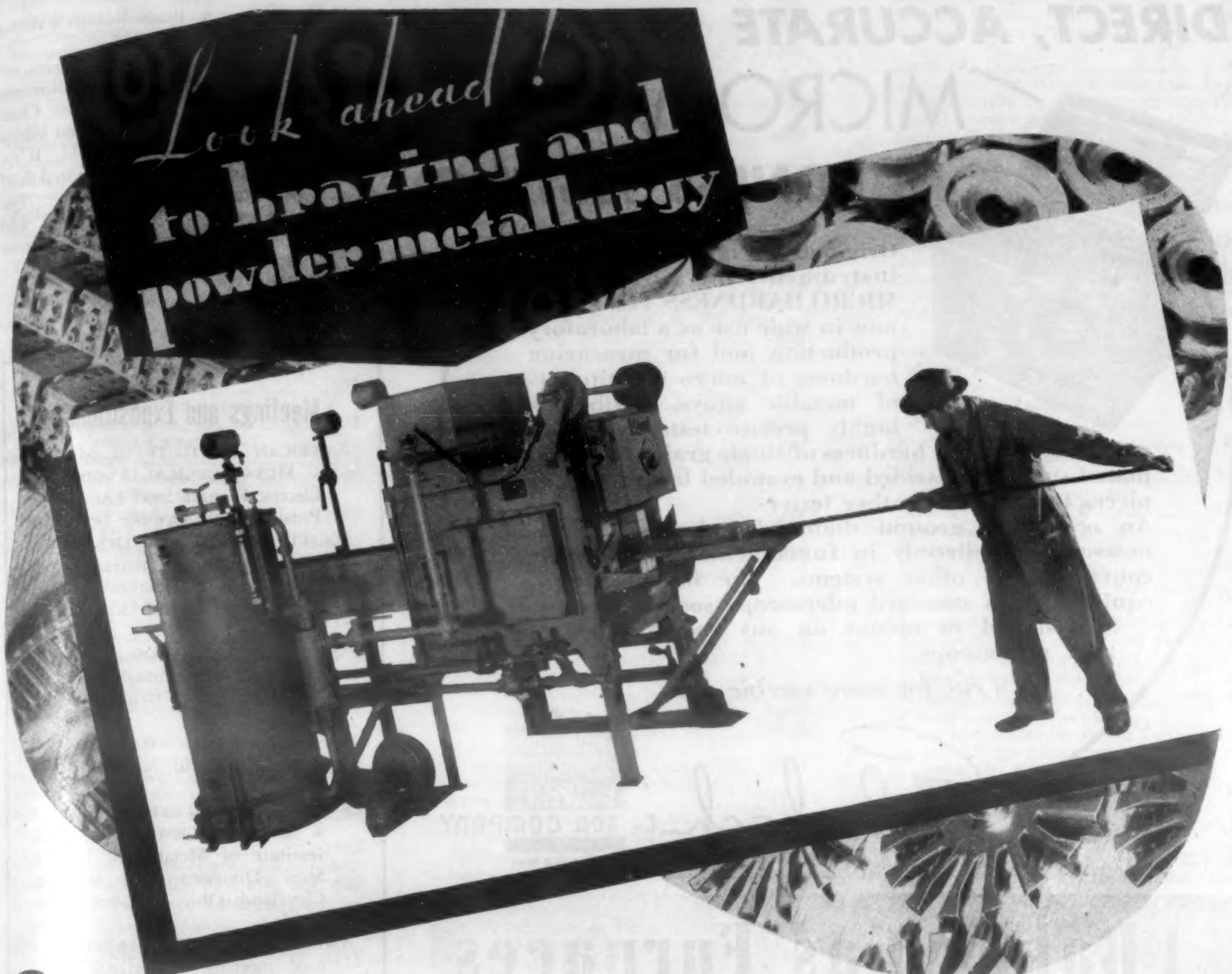
John Gjers, a Swede, invented the steel mill "soaking pit" in England in 1882. His crude holes in the ground were the forerunner of the big, modern intricate ingot-heating furnaces, to which clings the name, "soaking pit." Prior to Gjers' invention, the ingot was allowed to cool and was then reheated in gas-fired or coal-heated furnaces, obviously a wasteful, expensive practice. Gjers dropped the hot ingots into small holes lined with fire brick, which retarded the loss of heat from the exterior of the ingot long enough to permit the excess heat in the interior to soak through to the outside.

Aluminum News-Letter, Aluminum Co. of America, August 1944.

According to G. F. Begoon, manager, Precipitron department, Westinghouse, dirt particles are falling upon our cities today at the rate of 1950 tons per sq. mile per month in Pittsburgh, 1530 tons in Chicago, 1450 tons in Baltimore and comparable figures in other cities. Imagine all the damage this dirt causes to all types of machinery, etc.!

U. S. Steel News, U. S. Steel Corp. of Delaware, July 1944.

With the advent of this war, the capacity of by-product coke plants was insufficient to fill the demand, and it became necessary to revive beehive coke production. The ovens of the Connellsville district of western Pennsylvania had been out of service for about 20 yr. The stone in the oven walls and fronts had, in most cases, been hauled away and used elsewhere. Brickwork had partially fallen in. Machinery for drawing coke, electric larry cars for charging ovens, rails and trolley wires had been scrapped. Railroad sidings were often removed. Today the H. C. Frick Coke Co. operates more than 2900 reconstructed ovens in the Connellsville region, producing over 1,500,000 tons annually.



Great changes loom ahead in metal fabrication! You might well consider the low cost processing and speedy output possible in the fields of both production brazing and powder metallurgy.

We have prepared a bulletin with valuable information on brazing and powder metallurgy which is free for the asking. It contains sketches and photographs of brazing metal application and descriptive material on powder metallurgy methods. It also gives illustrations and detailed descriptions of the new Lindberg High Temperature Brazing Furnaces, one of which is pictured above.

These new furnaces are sturdy, carefully engineered units designed to operate at a temperature up to 2500° F. with precise temperature control and heating uniformity, plus a neutral controlled atmosphere. They cut production costs to the bone and on certain sub-assemblies give more strength, simplicity of fabrication and cleaner work. They have outstanding advantages in economy of operation, easy maintenance and operator convenience in loading and unloading.

In the larger sizes they may also be used for other purposes such as hardening high speed tools and dies for your toolroom and for bright annealing, normalizing and other heating operations requiring a protective atmosphere.

Write for Bulletin

You should know about new developments in these important metallurgical fields. Send for your copy today.

LINDBERG ENGINEERING COMPANY
2451 WEST HUBBARD STREET, CHICAGO 12, ILLINOIS

In Cleveland!
This furnace will be set up on exhibition at the Metals Show. Be sure to come to booth C-150.

Lindberg FURNACES

SUPER-CYCLONE for hardening, normalizing, annealing, tempering
CYCLONE for accurate, low-cost tempering and nitriding
HYDRYZING for scale-free and decarb-free hardening

Bulletin, Copper & Brass Research Assn., May 1944.

Two great copper distillation towers for the solvent recovery from penicillin are now in operation at the plant of Chas. Pfizer Co., Inc., Brooklyn, the largest manufacturer of penicillin in the world. It requires more than 21 quarts of cultured fluid to yield one gram of the dry powder. The fermentation cycle is unusually long, and exacting conditions of sterility, temperature and atmosphere control are required.

Meetings and Expositions

AMERICAN INSTITUTE OF MINING & METALLURGICAL ENGINEERS, Electric Furnace Steel Committee. Pittsburgh, Pa. October 5-6, 1944.

SOCIETY OF AUTOMOTIVE ENGINEERS, national aircraft engineering and production meeting. Los Angeles, Calif. October 5-7, 1944.

AMERICAN SOCIETY OF TOOL ENGINEERS, semi-annual meeting. Syracuse, N. Y. October 12-14, 1944.

ELECTROCHEMICAL SOCIETY, fall meeting. Buffalo, N. Y. October 12-14, 1944.

AMERICAN INSTITUTE OF MINING & METALLURGICAL ENGINEERS, Institute of Metals and Iron & Steel Divisions, fall meeting, Cleveland, Ohio. October 16-18, 1944.

AMERICAN WELDING SOCIETY, annual meeting. Cleveland, Ohio. October 16-19, 1944.

AMERICAN SOCIETY FOR METALS, annual convention. Cleveland, Ohio. October 16-20, 1944.

NATIONAL METAL EXPOSITION, Cleveland, Ohio. October 16-20, 1944.

WIRE ASSOCIATION, annual convention. Pittsburgh, Pa. October 16-20, 1944.

SOCIETY FOR EXPERIMENTAL STRESS ANALYSIS, fall meeting. Cleveland, Ohio. October 17-20, 1944.

AMERICAN INDUSTRIAL RADIUM & X-RAY SOCIETY, annual meeting. October 19-20, 1944.

INSTITUTE OF THE AERONAUTICAL SCIENCES, fall meeting. Dayton, Ohio. November 9-10, 1944.

SOCIETY OF AUTOMOTIVE ENGINEERS, national fuels and lubricants meeting. Tulsa, Okla. November 9-10, 1944.

SOCIETY OF THE PLASTICS INDUSTRY, annual meeting. New York, N. Y. November 13-14, 1944.

NATIONAL CHEMICAL EXPOSITION. Chicago, Ill. November 15-19, 1944.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, annual meeting. New York, N. Y. November 27-December 1, 1944.

trends

By Edwin F. Cone

Upswing in Magnesium

In the 25 yr. since 1919 there has been a progressive upswing in both the output and price of magnesium metal, according to an article in this issue on "Magnesium from Sea Water." In 1920 the production was only 20,017 lb.—in 1943 it was 65,430,040 lb. In 1919 the price per pound was \$1.83—it had declined to 22¢ in 1943. Originally it had been over \$5 per lb. in 1914. The 1944 ingot price is 20.5¢ per lb. freight allowed, compared to 14¢ per lb. for aluminum.

Contaminated Carbon Steel Scrap

The contamination of carbon steel scrap with alloys is becoming a more serious problem, it was stated at a recent meeting of the Steel Div., WPB. Some mills will accept mixed shipment of alloy and carbon grades, thus discouraging segregation. Some alloy scrap sells at below carbon scrap, thus creating a temptation to mix the two. The inventory of alloy steel scrap in the hands of the steel industry is over 50% triple alloy types, according to a WPB survey, yet consumption of the triple is under production.

Electric and Open-Hearth Alloy Steel

The production of electric steel for the first half of 1944 had been at the rate of 35% of the total alloy steel output. In January it was 36% falling to 33% in June. In 1939 the percentage was only 23%, gradually increasing to 30% in 1943 according to an analysis published in *The Iron Age.*

The volume of alloy steel made in open-hearth furnaces for the first half of 1944 was 65%. In January it was 64% rising to 67% in June. In 1939 the percentage was 77% gradually declining to 70% in 1943.

Whether the decline in electric output in June will continue remains to be seen. The increase from 1939 during the war has been a feature, culminating in 1944.

Alloy Steel Ingot Output by Types

A new table of statistics has this year been established by the American Iron and Steel Institute—Production of Alloy Steel Ingots (other than Stainless) in 1943. The data are as follows:

Ni	283,507
Mo	1,133,179
Mn	1,013,572
Cr	835,272
Ni-Cr	1,144,802
Cr-Mo	2,207,168
Ni-Mo	709,734
Ni-Cr-Mn—NE Steels	2,009,112
Ni-Cr-Mo—All others	1,727,886
All others	1,509,277
Total	12,573,509

Comparison with other years is not possible since such data have not been assembled.

The Cr-Mo steels lead at 2,207,168 tons with the NE steels second at 2,001,112 tons—interesting facts. The prominent role of molybdenum in this array is evident—of the total 7,787,079 tons or 61.8% contain that element.

Steel Employees' Victory Gardens

American steel companies are now donating acres of land to its employees for use as Victory gardens. Nearly 1700 acres are being worked and tended by 43,000 employees. These gardens in most cases are flourishing next to blast furnaces and steel mills on land provided by 50 steel companies, says the American Iron and Steel Institute. Approximately 1750 sq. ft. is the average space available to each employee.

Aluminum for Cans

Because of the growing shortage of paper and tin containers, the War Production Board has made available some aluminum for experimental purposes during third quarter, 1944, in the manufacture of aluminum cans for the packing of lard, baking powder, tobacco, tooth powder, pharmaceuticals, biscuits, etc.

World's Largest Oil Well

Claimed to be the world's deepest hole is an oil well in Pecos County, Texas. It is 15,279 ft. deep or nearly 3 miles. It was spudded on June 30, 1942, and finished in June, this year. It is 20 in. in diameter at the top, tapering gradually until it is 7¾ in. at the bottom. As soon as the drilling was completed, more than 600 threaded joints of 5½-in. outside diameter casing of steel were coupled together and lowered into the well. The weight of the casing was 156 tons.

Magnesium Production

Official data for the production of magnesium for 1943, just recently released by the Bureau of Mines, show that 183,584 net tons were produced. In 1942 the total was 48,963 tons. In 1939 the output was only 3,350 tons. Because of recent Government curtailment of production, the 1944 total will probably be less than last year, making the 1943 aggregate the peak for many years.